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WASTEWATER ENGINEERING AND MANAGEMENT PLAN FOR BOSTON HARBOR - EASTERN MASSACHUSETTS METROPOLITAN AREA EMMA STUDY.

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FOR
Boston Harbor - Eastern Massachusetts Metropolitan Area
EMMA STUDY

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HYGIENIC IMPACTS

EASTERN MASSACHUSETTS METROPOLITAN AREA

WASTEWATER MANAGEMENT STUDY

Prepared By

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NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

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I. INTRODUCTION

The Boston Harbor-Eastern Massachusetts Metropolitan Area Wastewater Management Study is a joint effort by the Metropolitan District Commission (MDC), the U.S. Army Corps of Engineers, and various State, Federal and regional agencies to develop a comprehensive wastewater management plan for the Boston Harbor-Eastern Massachusetts Metropolitan Area (BH-EMMA). Major emphasis in the study has been placed on determination of the future size of the Metropolitan Sewerage District and the development and assessment of wastewater management systems that are in accordance with the goals, objectives, and requirements of the Federal Water Pollution Control Acts Amendments of 1972.

The BH-EMMA Study Area, encompassing 109 communities within a 30 mile radius of the city of Boston contains 1760 square miles of land, and a population of over 3 million. Forty three of these communities are currently members of the MDC Metropolitan Sewerage District. A large portion of these 109 communities lie within the following regions:

1. Boston Harbor
2. Mystic River Watershed
3. Neponset River Watershed
4. Charles River Watershed
5. Ipswich River-North Coastal
6. North River-South Coastal
7. Sudbury, Assabet and Concord Watersheds (SUASCO)

The Metropolitan District Commission commissioned the engineering firm of Metcalf and Eddy, Inc. to design four regional water oriented concepts for the study area. The primary focus of these concepts is the expansion or contraction of the Metropolitan Sewerage District. In addition, the Army Corps of Engineers, recognizing the 1972 Federal Water Pollution Control Act Amendments emphasis on alternative wastewater management techniques to prevent direct discharge of pollutants to the Nations waters, commissioned the engineering firm of Whitman and Howard, Inc. to develop a land application alternative for the study area. This concept (concept 5) is designed to transport 180 MGD (design year 2000) from 5 regional wastewater treatment facilities located on tributaries to Boston Harbor, to land application sites in Southeastern Massachusetts. All land sites lie outside the study area, due to the lack of available and suitable land within the study area.

The intent of this report is to determine the potential beneficial, neutral and adverse impacts which the implementation of each alternative concept for wastewater management may have on the public health of the study area.

This Appendix contains three major sections. The first section (II) provides an evaluation of existing conditions in the study area. Establishment of existing conditions in the areas affected by the various plans for wastewater management is quite necessary, as it creates a baseline from which impact or change can be measured. This section includes a short description of each watershed, a discussion of each

watersheds major point and non-point sources of water pollution, a presentation of the most recent water quality data, and a discussion of the effects of pollution on health related uses of water in the area.

The second section (III) contains an assessment of potential hygienic impacts or changes that may be caused by the implementation of each of the five alternative plans for wastewater management in the BH-EMMA area, and the plan recommended by the BH-EMMA Technical Subcommittee.

The World Health Organization defines health as "a state of complete physical, mental and social will being, not merely the absence of disease or informity."

Thus, this impact assessment is concerned not only with the elimination or magnification of potential direct causes of physical disease, such as pathogenic organisms or hazardous chemicals, but also with changes in environmental conditions affectiong the social and mental well-being of inhabitants of the study area. For instance, adverse changes, such as excessive algal growth in a stream, can cause rather depressing, unpleasant conditions for the inhabitants of a watershed. In addition, such adverse changes in environmental quality may encourage further deterioration of conditions related to the public health. A positive hygienic impact assessment must not only involve elimination of existing adverse situations, but also the prevention of the occurrence of new hazardous conditions.

The addendum to this report supplies background information on both public health hazards found in wastewater and sludges, and the effectiveness of various wastewater and sludge treatment processes in the removal of hazardous substances. Those who are unfamiliar with this field will find this information helpful in providing a better understanding of the sections on baseline conditions and impact assessment.

II. ASSESSMENT OF BASELINE CONDITIONS

The purpose of this section is to establish existing conditions in the areas affected by the plans for wastewater management in the Boston Harbor, Eastern Massachusetts Metropolitan area (BH-EMMA). Establishment of existing conditions is quite necessary in impact assessment as it creates a baseline from which change or impact can be measured. The study area is divided into seven subareas by watershed or coastal region, as each major subarea has its own unique problems, which lead to variations in impact for each concept. The subareas are listed below:

A. Boston Harbor

B. The Mystic River Watershed

C. The Neponset River Watershed

D. The Charles River Watershed

E. The North River and South Coastal Region

F. The Ipswich River and North Coastal Region

G. The SUASCO (the Sudbury, Assabet and Concord River Watersheds)

The following information will be presented for each selected area:

1. Description of the area - a brief discussion of the characteristics of the area.

2. Sources of pollution - a descriptive survey of water pollution problems in the area.

3. Water quality data - in an attempt to quantify pollution levels, water quality data collected from various recent reports is presented. Parameters reported are: Dissolved oxygen, Biochemical oxygen demand, Ammonia, Nitrates, Total phosphorus, Alkalinity, Suspended solids, Turbidity, Color, Chlorides, and Coliform bacteria. Information on concentrations of trace metals, pesticides, and organic chemicals is also an important factor in assessing pollution levels, as low concentrations of these substances are hazardous to man and wildlife.

However, data on levels of these substances cannot be reported for all waters within this study area, as very few studies have measured the levels of the parameters. The significance of each of the above parameters mentioned as a measure of pollution is shown in Table 1.

Since the purpose of this report is to assess public health impacts, emphasis must be placed on parameters directly related to health hazards. Before a certain parameter can be designated as a health hazard, the use (both present and potential) of the body of water must be considered. Health related uses and their relation to water quality classification goals set by the Massachusetts Division of Water Pollution Control are listed below:

TABLE 1

EXPLANATION OF WATER QUALITY PARAMETERS

Dissolved Oxygen (DO)	A measure of the uncombined oxygen present in water that is available to aquatic life.
Biochemical Oxygen Demand (BOD)	A measure of the amount of oxygen consumed in the biological processes that breakdown organic matter in water. The greater the degree of pollution, the greater the BOD.
Ammonia	Raw sewage contains approximately 20 mg/1 nitrogen; 90% of this nitrogen is in the form of ammonia. Ammonia is toxic to fish. It has a high oxygen demand, and is readily oxidized to nitrates. Ammonia also readily combines with chlorine to form compounds toxic to aquatic life.
Nitrates	Nitrate nitrogen is the end product in the oxidation of ammonia. Nitrogen in this form is most readily taken up by plants.
Phosphorous	Phosphorous is an essential nutrient for plant growth. It is most commonly found in domestic wastes (60% from detergents), industrial wastes, and agricultural runoff. Phosphorous, nitrates and other nutrients, when present in the right ratios, are the prime cause of algal blooms.
Suspended Solids	Suspended solids are solids that can be removed by passing water through a filter. Suspended solids contribute to turbidity in water.
Turbidity	Turbidity is the measure of the clarity of water. The standard measure for turbidity is Jackson Turbidity Units, which are related to scattering and adsorption of light in a sample.
Color	Color is undesirable for esthetic reasons. It is determined by a visual comparison of a sample with known concentrations of colored solutions, and is expressed in standard units of color.
Alkalinity	Alkalinity is the measure of alkaline or basic materials in water.

TABLE 1 (Cont.)

Chlorides	Chlorides are a measure of the chloride salt content of water. These substances occur naturally in seawater and unnaturally in freshwater due to pollution from such sources as urban runoff and industry.
Coliforms	Coliforms are bacteria used as indicators of fecal pollution. Although some of these bacteria inhabit natural environments, one type, the fecal coliform, inhabits only the intestines of warm blooded animals.
Trace Metals	Trace metals are elements of a metallic nature present in wastewater in small concentrations largely due to industrial sources. Some trace metals may be beneficial in small concentrations and toxic at larger concentrations, while other trace metals, like mercury, are toxic in very small amounts.
Pesticides	Pesticides are agents used to kill unwanted species or "pests". Most pesticides used today are of the synthetic organic type. Large quantities of these substances are highly toxic to man and wildlife, and persistent lower levels of these substances have been linked to cancer in man.
Organic Chemicals	Organic chemicals are compounds consisting of carbon, usually in combination with hydrogen, oxygen or sulfur. Many of these substances are present in polluted water due to both industrial discharge and natural sources, such as runoff from swamps. Many of these compounds, especially those containing the elements chlorine and bromine, have been linked to cancer in man.

Use	Water Quality Classification
1. Water Supply	Class A
2. Recreation	
Contact	Class B, SB
Non-contact	Class C, SC
3. Shellfish Harvesting	
Restricted	Class SB
Open	Class SA

The Division of Water Pollution Control has set Water Quality Classifications for each water body in the study area. These classifications are listed at the beginning of each Water Quality Data Table for each watershed. The values of the parameters in these tables may be compared with the standards set for water use by State and Federal agencies (Table 2).

4. The effects of pollution - the effects of pollution on health related uses are evaluated.

Finally, a section on Areas affected outside the Study Area (section H) is provided to set baseline conditions for specific land application sites in southeastern Massachusetts outside the BH-EMMA area.

A. Boston Harbor

Boston Harbor has great potential use as a major recreational resource for the Boston Area, an area which contains over 3.1 million people. The Harbor contains "47 square miles of water, 180 miles of tidal shoreline, and 30 islands with a total area of about 1,400 acres" (1). In 1968 the Massachusetts legislature, recognizing the Harbor's great potential value, authorized through the passage of Chapter 742, H. 4884 of the General Laws, the purchase of sixteen islands presently in private hands. These islands are to be developed, under the supervision of the Department of Natural Resources, for the purposes of conservation and recreation. However, effective development of the Harbor as a recreational resource depends on one major factor: the quality of the water. Development of beaches and other water related recreation facilities will be a wasted effort if the water quality is below standards considered safe for recreational use.

At the present time the water quality in Boston Harbor is a major problem. Both swimming and shellfish harvesting are endangered in many areas by pollution from combined sewer overflows, stormwater runoff, treatment plant sludge, oil spills, watercraft discharges, and tributary streams. These sources of pollution must be dealt with before a successful program of resource development can be undertaken.

TABLE 2

WATER QUALITY STANDARDS
(ppm unless otherwise designated)

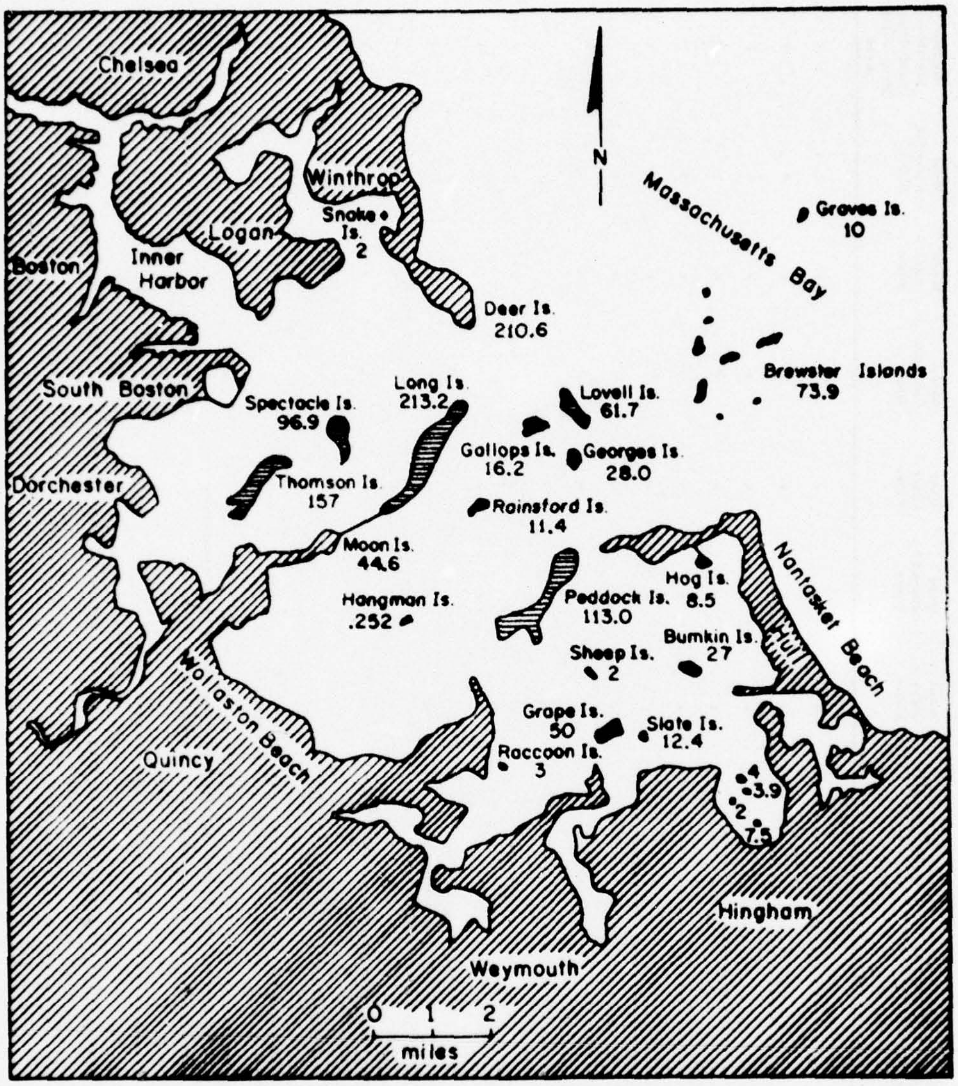
Water Quality Parameter	Proposed Interim Primary Drinking Water Standards	EPA Criteria for Raw Water Used for Water Supplies	EPA Criteria for Contact Recreation Water	EPA Criteria for Non-Contact Recreation Water	Mass Class A Water	Mass Class SA Water	Mass Class B Water	Mass Class SB Water	Mass Class C Water	Mass Class SC Water	National Shellfish Sanitation Prog. Open Area	National Shellfish Sanitation Restricted Area
Total Coliforms	1*	10,000/100ml			50/100ml	70/100ml	1000/100ml	700/100ml	b	b	0-70/100ml	70-700/100ml
Fecal Coliforms		2,000/100ml	200/100ml	2000/100ml					b	b		
Turbidity	1 TU**		4' secchi disk		a	b	b	b	b	b		
Color		75 units			a	b	b	b	b	b		
Odor		none			a	none	b	b	b	b		
pH		5-9	6.5-8.3		a	6.8-8.5	6.5-8.0	6.8-8.5	6.0-8.5	6.5-8.5		
Dissolved Oxygen					5	6.5	5	5	3	3	c	c
Ammonia		0.5			c	c	c	c	c	c	c	c
Nitrates (as N)	10.	10			c	c	c	c	c	c	c	c
Cyanide	0.2				c	c	c	c	c	c	c	c
Phosphorous			.025-.1		c	c	c	c	c	c	c	c
Arsenic	0.05	0.1			c	c	c	c	c	c	c	c
Barium	1.	1.0			c	c	c	c	c	c	c	c
Boron		1.0			c	c	c	c	c	c	c	c
Cadmium	0.010	.01			c	c	c	c'	c	c	c	c
Chromium	0.05	.05			c	c	c	c	c	c	c	c

Water Quality Parameter	Proposed Interim Primary Drinking Water Standards	EPA Criteria for Raw Water Used for Water Supplies	EPA Criteria for Contact Recreation Water	EPA Criteria for Non-Contact Recreation Water	Mass Class A Water	Mass Class SA Water	Mass Class B Water	Mass Class SB Water	Mass Class C Water	Mass Class SC Water	National Shellfish Sanitation Prog. Open Area	National Shellfish Sanitation Restricted Area
Chlorides		250			c	c	c	c	c	c	c	c
Copper		1			c	c	c	c	c	c	c	c
Fluoride	1.4-2.4***				c	c	c	c	c	c	c	c
Lead	0.05	0.05			c	c	c	c	c	c	c	c
Iron		0.3			c	c	c	c	c	c	c	c
Manganese		0.05			c	c	c	c	c	c	c	c
Mercury	0.002	0.002			c	c	c	c	c	c	c	c
Selenium	0.01	0.01			c	c	c	c	c	c	c	c
Silver	0.05	0.05			c	c	c	c	c	c	c	c
Zinc		5			c	c	c	c	c	c	c	c
Sodium		-			c	c	c	c	c	c	c	c
Sulfates		250			c	c	c	c	c	c	c	c
Phenols		0.001			c	c	c	c	c	c	c	c
Oil & Grease		0			c	c	c	c	c	c	c	c
ABS		0.5			c	c	c	c	c	c	c	c
CCE	0.7	0.3			c	c	c	c	c	c	c	c

Water Quality Parameter	Proposed Interim Primary Drinking Water Standards	EPA Criteria for Raw Water Used for Water Supplies	EPA Criteria for Contact Recreation Water	EPA Criteria for Non-Contact Recreation Water	Mass Class A Water	Mass Class SA Water	Mass Class B Water	Mass Class SB Water	Mass Class C Water	Mass Class SC Water	National Shellfish Sanitation Prog. Open. Area	National Shellfish Sanitation Restricted Area
Pesticides												
Aldrin		0.001			c	c	c	c	c	c	c	c
Chlordane	0.003	0.003			c	c	c	c	c	c	c	c
DDT		0.05			c	c	c	c	c	c	c	c
Dieldrin		0.001			c	c	c	c	c	c	c	c
Endrin	0.0002	0.0005			c	c	c	c	c	c	c	c
Heptachlor	0.001				c	c	c	c	c	c	c	c
Heptachlor Epoxide	0.0001	0.0001			c	c	c	c	c	c	c	c
Lindane	0.004	0.005			c	c	c	c	c	c	c	c
Methoxychlor	0.1	1.0			c	c	c	c	c	c	c	c
Toxaphene	0.005	0.005			c	c	c	c	c	c	c	c
Parathion		0.1			c	c	c	c	c	c	c	c
Herbicides												
2, 4D	0.1	0.02			c	c	c	c	c	c	c	c
2, 4 5T		0.002			c	c	c	c	c	c	c	c
2, 3, 5-TP	0.01				c	c	c	c	c	c	c	c

a. naturally occurring concentrations
b. none in concentrations that would impair uses assigned
c. none in concentrations that would be harmful to human, animal or aquatic life for the designated water use.

* arithmetic mean of all samples examined per month (MF)
** less than 5TU are allowed if supplies demonstrate turbidity does not interfere with disinfection and microbiological determinations
*** temperature dependent



BOSTON HARBOR ISLANDS

Figure 1

2. Sources of Pollution in the Harbor

The major sources of pollution in the Harbor are:

a. Municipal sewage
b. Digested sludge from Deer and Nut islands waste treatment facilities
c. Combined sewer overflows
d. Industry
e. Stormwater runoff
f. Oil spillage
g. Polluted tributary streams
h. Refuse and debris
i. Waste from ships and pleasure boats

These major sources are discussed in more detail below.

a. Municipal Sewage

One of the sources of pollution in the harbor is the discharge of primary treated sewage, with disinfection, from the two major municipal sewage systems operated by the Metropolitan District Commission. Approximately 440 million gallons per day of primary treated sewage flow from two MDC wastewater treatment plants located on Deer and Nut Islands (2). The South Metropolitan Sewage System serves 21 communities, including portions of Boston, Newton, Brookline, Hingham and Quincy (see Table 3), with a contributing population of 616,000. This system transports an average flow of 140 MGD of sewage to a treatment plant on Nut Island where it is given primary treatment consisting of pre-chlorination, coarse screening and grit removal, pre-aeration of influent for 20 minutes, primary sedimentation, and post-chlorination for 20 minutes with a chlorine residual of 1.0 mg/l. The treatment plant has three outfalls discharging treated effluent to Quincy Bay, and an emergency relief outfall which discharges pre-chlorinated and screened effluent to Hingham Bay, when the flow exceeds approximately 250 MGD and/or at periods of high tide.

The North Metropolitan System serves 22 communities, including parts of Boston, Brookline, Newton and Milton, with a contributing population of 1,303,000 (see Table 4). This system transports an average flow of 300 MGD of sewage to Deer Island where it is also given primary treatment, and chlorination for 20 minutes, with a chlorine residual ranging from .2 to 1.2 mg/l. The Deer Island treatment plant has two outfalls which discharge primary treated effluent to Boston Harbor, and three emergency outfalls which discharge primary treated effluent and are activated, successively, when influent flow rates exceed 400, 500 and 600 MGD.

Concentrations of various materials in effluents from both Deer and Nut Islands are given in Tables 5 and 6.

TABLE 3

SOUTH METROPOLITAN SEWAGE SYSTEM

TO NUT ISLAND (2)

THE TOTAL AND CONTRIBUTING POPULATIONS ALONG WITH THE ULTIMATE SEWERED AREA OF EACH CITY OR TOWN CONTRIBUTING TO NUT ISLAND TREATMENT PLANT AS OF DECEMBER 31, 1975 ARE TABULATED BELOW

CITY OR TOWN	TOTAL POPULATION 1971 STATE CENSUS	CONTRIBUTING POPULATION	ULTIMATE SEWERED AREA SQUARE MILES
Ashland	8,770	1,076	9.40
Boston (Part Of)	160,121	160,060	16.96
Braintree	35,924	31,510	13.44
Brookline (Part Of)	20,617	20,616	3.95
Canton	17,181	9,141	17.73
Dedham	27,384	24,317	9.55
Framingham	60,623	48,334	22.50
Hingham	7,296	4,089	2.50
Holbrook*	11,796	-----	4.50
Milton (Part Of)	24,853	23,006	8.56
Natick	30,636	21,391	14.58
Needham	30,728	26,718	7.81
Newton (Part Of)	49,936	49,827	8.12
Norwood	30,963	30,822	10.14
Quincy	89,598	89,396	11.39
Randolph	28,406	7,623	6.25
Stoughton	23,419	6,214	15.55
Walpole	17,881	5,385	20.52
Wellesley	26,863	21,751	9.89
Westwood	13,538	4,784	9.24
Weymouth	55,677	29,849	16.22
TOTAL	772,210	615,909	238.80

*Holbrook -- became a member of the system January, 1971, but is not contributing sewage to the system.

TABLE 4

NORTH METROPOLITAN SEWAGE SYSTEM

TO DEER ISLAND (2)

THE TOTAL AND CONTRIBUTING POPULATIONS ALONG WITH THE ULTIMATE SEWERED AREA OF EACH CITY OR TOWN CONTRIBUTING TO DEER ISLAND TREATMENT PLANT AS OF DECEMBER 31, 1972, ARE TABULATED BELOW

CITY OR TOWN	TOTAL POPULATION 1971 STATE CENSUS	CONTRIBUTING POPULATION	ULTIMATE SEWERED AREA SQUARE MILES
Arlington	52,319	52,214	4.64
Bedford	5,750	5,750	1.42
Belmont	29,053	27,779	3.79
Boston (Part Of)	464,713	464,584	22.23
Brookline (Part Of)	32,265	32,259	1.38
Burlington	23,046	15,045	8.97
Cambridge	85,954	85,750	5.42
Chelsea	28,045	28,012	2.06
Everett	41,269	41,217	2.91
Lexington	33,412	26,433	15.78
Malden	56,176	56,098	4.14
Medford	62,162	62,092	5.98
Melrose	32,426	32,372	3.81
Milton (Part Of)	2,227	2,227	0.42
Newton (Part Of)	38,620	38,535	6.28
Reading	22,616	14,466	9.70
Revere	42,650	40,431	5.55
Somerville	84,790	84,684	3.96
Stoneham	21,308	20,376	4.24
Wakefield	24,605	22,111	6.35
Waltham	57,477	42,271	11.39
Watertown	38,531	38,450	3.82
Wilmington	17,251	180	15.37
Winchester	22,797	22,782	5.31
Winthrop	19,347	19,330	1.59
Woburn	34,685	27,688	12.23
TOTALS	1,373,494	1,303,136	168.74

TABLE 5

CHARACTERISTICS OF DEER AND NUT ISLAND EFFLUENTS (2) (3) (ppm)

	Deer Island	Nut Island
Suspended Solids	69	121
Grease, Petroleum & Other Solubles	10.9	22.1
Settleable Solids	1.28	.7
Coliforms (per 100 ml)	1,066	800
BOD_5	94.5	95
*Nitrates (NO_3-N)	.77	
*Nitrites (NO_2-N)	.09	
*Ammonia (NH_3-N)	15.6	
*Kjeldahl Nitrogen	29.2	
*Phosphorus Ortho	4.8	
Total	9.0	

*Monthly tests performed by MDC, Sewerage Division for the year 1973

TABLE 6

RANGE OF TRACE METALS CONTENT IN DEER AND NUT ISLAND EFFLUENTS (ppm) (3)*

	Deer Island	Nut Island
Arsenic	.006-.017	.003-.020
Cadmium	.016-.34	.01-.05
Chromium	.01-.14	.01-.11
Copper	.02-.70	.01-.50
Lead	.01-.20	.02-.12
Mercury	.0004-.0019	.0001-.0013
Nickel	.07-.18	.02-.20
Silver	.01-.06	.01-.05
Zinc	.4-1.6	.20-.80

*Monthly tests performed by MDC, Sewerage Division for the year 1973.

It is questionable whether the treatment now in use at these plants is effective enough to eliminate all materials hazardous to the public health. First of all, although chlorination presently removes over 99.99% of the coliform bacteria at both treatment plants; it is probably ineffective in virus removal. Secondly, primary treatment cannot remove large amounts of trace metals, which may be concentrated in fish and shellfish. In addition, design flow of 112 MGD at Nut Island is already exceeded, and flows above this design flow receive less efficient treatment. Also, when the influent rate exceeds 250 MGD and/or at periods of high tide, low quality effluent, receiving only pre-chlorination and screening, is discharged to Hingham Bay through the emergency outfall. Finally, the effectiveness of wastewater treatment at these two MDC operated plants is impaired by the method of sludge disposal. Many of the pollutants removed in the treatment process eventually reach the Harbor waters when digested sludge is discharged.

The U.S. Environmental Protection Agency and the Massachusetts Division of Water Pollution Control have drafted discharge permits for both the Deer and Nut Island wastewater treatment plants. These permits were drafted in accordance with the Federal Water Pollution Control Act Amendments of 1972, which require publicly-owned waste treatment plants to provide a minimum of secondary treatment by July 1, 1977, and to apply best practicable control technology by July 1, 1983. The permit for Nut Island treatment plant authorizes the Nut Island plant to discharge primary effluent from the three plant outfalls to Quincy Bay, until June 30, 1977. The 12 consecutive monthly average concentration of BOD and total suspended solids (TSS) in this effluent is to be 78 percent and 56 percent of the 12 consecutive monthly average concentration of BOD and TSS in the plants influent. Until June 30, 1977 the MDC is also authorized to discharge from the plants emergency relief outfall to Hingham Bay during periods when the influent flow rate exceeds 250 MGD and/or at periods of abnormally high tides. This effluent must receive preliminary screening and disinfection prior to discharge.

The permit for the Deer Island treatment plant authorizes the MDC Deer Island Plant to discharge primary treated effluents to Boston Harbor from the two plant outfalls until June 30, 1977. The 12 consecutive monthly average concentration of BOD and TSS in the effluent, measured at a point prior to mixing with digested sludge (see P. 17) shall be equal to or less than 74 percent and 58 percent respectively of the 12 consecutive monthly average concentration of BOD and TSS in the plants influent. Until June 30, 1977, the Deer Island plant is authorized to discharge primary treated effluent from its three emergency outfalls when the influent flow rate exceeds 400, 500 and 600 MGD. Also, until this date, the MDC is allowed to discharge untreated stormwater/sanitary sewage overflow to tributaries of Boston Harbor from 18 overflow points in its sewer system.

By July 1, 1975 the MDC is to submit the results of this study (Boston Harbor - Eastern Massachusetts Metropolitan Area Wastewater Management Study) to EPA and the Massachusetts Division of Water Pollution Control for approval. Based on the results of this study

an implementation schedule shall be developed. The wastewater treatment facilities to be constructed in accordance with the schedule shall be designed to provide a minimum of secondary treatment.

Other conditions of the permit cover discharge of digested sludge and construction of sludge disposal facilities to terminate this discharge, development of a sewer use ordinance, monitoring and reporting requirements, and plans to minimize discharge of pollutants from combined sewer overflows and by-passes.

b. Sludge

Sludge consists of solids separated from liquids, such as wastewater during processing.

Sludge treatment at Nut Island is accomplished by modified high rate digestion. (Digestion allows anaeobic bacteria to decompose organic solids to more stable forms, and also reduces volume). Digested sludge is disposed of through a pipeline extending 4.2 miles from the treatment plant into deep tidal water on the south side of President Roads.

Treatment of sludge at the Deer Island treatment plant is accomplished by separate sludge thickening followed by high rate digestion. The sludge is diverted after digestion to the main sewage outfall pipes on the north side of President Roads where it is mixed with chlorinated effluent for about 10 minutes before it reaches the harbor waters (2).

The disposal of sludge through direct discharge into receiving water, reduces the overall effectiveness of the treatment plant in removing bacteria, oxygen demanding materials, and negates whatever nutrient and metal removal there might be. Because neither of the MDC sewage treatment plants directly disinfect their sludge, coliform bacteria concentrations in the digested sludge are high, sometimes higher than the bacterial concentrations of incoming sewage as digestion tanks create an ideal environment for bacterial growth. In addition, bacteria in digested sludge are better able to survive in a salty environment, like the ocean, than bacteria in the effluent, as digestion tanks are effectively a high salt culture medium due to salt water infiltration. Bacteria in this culture medium can mutate and are thus better able to survive the salty ocean environment (4).

Also, although sludge is discharged every day for 2 hours on the outgoing tide, all the sludge is not carried out to sea. The firm Hydroscience, Inc., employed by the Massachusetts Division of Water Pollution Control to develop a water quality model for Boston Harbor, found that 15-20% of sludge solids were eventually deposited west of Deer Island, and the New England Aquarium estimates a much higher percentage is deposited in the Harbor (5).

Finally, the location of both the sewer and sludge outfalls creates a cross-fire in the center of the harbor where the islands are located, endangering the recreational potential of this area.

Characteristics of Deer and Nut Island sludge are given in Table 7 (3).

The MDC is currently involved in a program to eliminate the disposal of sludge to the Harbor waters. Designs are being made for an incinerator located at Deer Island to handle both Deer and Nut Island treatment plant sludges. Both EPA and the Massachusetts Department of Public Health are studying the impact of incineration in the Harbor on air quality. Plans have not been made for disposal of the incinerator ash. Two possibilities for ash disposal are being considered:

1. Use of ash as fill to expand Deer Island

2. Disposal in a sanitary landfill after stabilization in lagoons.

The permit drafted for the discharge from Deer and Nut Islands wastewater treatment plants allows these plants to discharge digested sludge into Boston Harbor only during the four hour period beginning at high tide, until June 30, 1977. By January 1, 1976 the MDC is to submit final plans for sludge disposal to EPA and the Commonwealth of Massachusetts for approval. Discharge of digested sludge to the Harbors waters will be terminated upon construction of the approved sludge disposal facilities.

TABLE 7

CHARACTERISTICS OF DEER AND NUT ISLAND SLUDGES (ppm) (3)*

Organic (avg. in ppm)	Deer Island	Nut Island
Ammonia (NH_3-N)	314	
Kjeldahl Nitrogen	1549	
Phosphorous		
Ortho	80	
TOTAL	472	
Metals (range in ppm wet weight)		
Arsenic	.140-.300	.032-.350
Cadmium	1.8-4	.80-5
Chromium	6.15-59	.5-8
Copper	12-104	.3-26
Lead	10-34	4-16
Mercury	.09-.455	.085-.120
Nickel	2.1-15	.1-15
Silver	.37-3.6	.4-1.50
Zinc	34-256	.5-70

*Monthly tests performed by the MDC Sewerage Division for the year 1973.

c. Combined Sewer Overflows

Portions of Boston, Cambridge, Chelsea, Somerville and Brookline are served by combined sewer systems. In all, there are approximately 125 combined sewer outlets to Boston Harbor and its tributary streams, serving an area of approximately 12,350 acres (6). Seventy-five of these overflows are from the City of Boston sewer system, and 18 are from MDC interceptor sewers. During dry weather periods, wastewater is transported through these combined sewers to one of the MDC wastewater treatment plants; however, during periods of rainfall, these combined sewers overflow, discharging untreated wastes to both the Harbor and its tributaries. These untreated wastes are a major source of contamination in bathing beaches and shellfish harvesting areas. In addition to overflows during periods of rainfall, many of these combined sewers discharge wastes into the Harbor at low tide, during dry weather, due to missing or malfunctioning tidegates and regulators. These faulty appurtenances also allow large amounts of seawater to enter the system at high tide. The increased load due to seawater infiltration decreases the removal efficiency of the waste treatment plant.

The New England River Basins Commission's "Interim Report on Combined Sewer Overflows to Boston Harbor" (6) reports that peak dry weather flows may exceed the capacity of some sewers within the near future. In fact, peak flows in the Dorchester Interceptor are quite likely exceeded at the present time (see Table 8). Frequency of overflow is also calculated in this report. Results of these calculations show that some combined sewers overflow quite often, such as the Dorchester Interceptor which overflows over 90 times a year (see Table 9).

The MDC is currently involved in a program to repair 200 tidegates and regulators in the Boston Main Drainage system. After these tidegates and regulators are repaired they are turned over to the City of Boston for maintenance. To date, 90% of these appurtenances have been repaired, and the MDC has undertaken a project to repair tidegates in East Boston and Charlestown. However, effective elimination of this source of pollution depends on the effective maintenance of rehabilitated tidegates, the implementation of projects to repair regulators and tidegates in other towns bordering the Harbor, and the implementation of an overall plan to either eliminate or treat overflows from combined sewers.

The U.S. Environmental Protection Agency and the Massachusetts Division of Water Pollution Control have drafted permits to both the MDC and the City of Boston for its combined sewer and stormwater overflows. These permits authorize the discharge of untreated stormwater/sanitary sewage overflow and bypass to Boston Harbor and its tributaries until June 30, 1977. Both permits require that the MDC and the City of Boston shall cooperate to make plans to minimize discharge of pollutants from combined sewer overflows and bypasses. The permit for the City of

TABLE 8 (6)

INTERCEPTORS WHERE PEAK DRY WEATHER FLOWS

MAY EXCEED CAPACITY PRIOR TO 2020

Name of Intercepter	Capacity of Interceptor (cfs)	Date When Peak Flow Exceeds Capacity
Neponset River Valley Sewer and Dorchester Interceptor	40	Present
East Side Interceptor, Boston	51	1975
West Side Interceptor, Boston	51	1985
Alewife Brook Sewer, Somerville	64	1990
Stony Brook Valley Sewer, Boston	48	2010
Chelsea Branch Sewer, Chelsea	15	2010
South Charles System, Boston	116	2015
North Metropolitan Sewer, Chelsea	232	2015

TABLE 9(6)
Frequency of Overflows Per Year
From Each Combined System

Name of Interceptor	Number of Overflow Occurrences Per Year 1970	1995	2020
Alewife Brook Sewer, Cambridge	8	8	8
Alewife Brook Sewer, Somerville	1	1	4
Cambridge Branch Sewer, Cambridge-[1]Charles River, R.M. 6.0 to 1.7	10	11	11
Cambridge Branch Sewer, Cambridge-Charles River, R.M. 1.7 to 1.2	35	35	35
South Charles System, Boston	0	0	0
B.U. Chlorination and [2] Detention Chamber	56	61	64
Boston Marginal Conduit Charles River, R.M. 2.8 to 1.2	11	11	11
Boston Marginal Conduit Charles River, R.M. 2.8	32	35	38
Boston Marginal Conduit Charles River-Tidewater	50	65	88
Somerville-Medford Branch Sewer, Somerville	72	79	80
Cambridge Branch Sewer, Somerville	46	49	50
N. Metropolitan Sewer, Chelsea	7	18	27
Chelsea Branch Sewer, Chelsea	63	66	71
Charlestown Branch Sewer, Charlestown	45	47	50
E. Boston Branch Sewer, E. Boston	26	27	27
East Boston Low Level Sewer and Moore St. Interceptor	24	26	27
East Side Interceptor, Boston	69	90	0[3]
Roxbury Canal Sewer, Roxbury	2	3	3
Dorchester Brook Sewer, Dorchester	44	47	51
S. Boston Interceptor, S. Boston	46	46	46
Neponset River Valley Sewer and Dorchester Interceptor, Dorchester	93	0[4]	0[4]

(1) Assumes completion of the North Charles Relief Sewer which is presently under construction

(2) These are the rainfall intensities and the number of times overflows to the detention chamber occur. In many cases, overflows to the river will not occur.

(3) Continuous overflow of 4 cfs dry weather flow in 2020.

(4) Continuous overflow of 4 cfs dry weather flow in 1995 and 15 cfs dry weather flow in 2020.

Boston specifically requires reconstruction of three interceptors and institution of a program to separate sanitary sewer connections from storm sewers. It further specifies that the city's Moon Island Facility, which holds sewer overflows, and discharges at high tide to Boston Harbor and Quincy Bay, shall hold the untreated sewage until one hour after high tide, at which time the sewage can be discharged for a period not to exceed 3 hours. This discharge should be chlorinated during the months of May through September (beginning May 1975). The Moon Island Facility has been implicated in many pollution incidents in Quincy Bay. It should be eliminated through construction, sewer separation projects, and plans to minimize combined sewer overflow, mentioned in the permit.

d. Industry

Although most industries in the Boston Harbor area discharge their wastes to the municipal sewer system, their importance as the source of toxic substances found in the Harbor's waters and sediments warrants a separate category. Metcalf and Eddy, Inc., estimate that 28% (127 MGD) of the discharges to MDC sewage treatment plants are of industrial origin (7). Jason M. Cortell and Associates (8) surveying large industries in the Eastern Massachusetts area found that less than 20 MGD of the industrial discharge to the MDC system is process water. Information on the concentrations of these toxic substances in industrial effluents is scanty. However, the New England Aquarium has measured the concentrations of toxic metals in the Harbor waters and sediments; results of this study are discussed in the "Water Quality" section.

The MDC controls the discharge of hazardous substances into its sewerage system through rules and regulations covering discharge of sewage, drainage, substances or wastes. Current rules covering the discharge of toxic metals and non-metals are summarized on page 24.

The U.S. Environmental Protection Agency, according to Section 307 (b) (1) of the Federal Water Pollution Control Act Amendments of 1972 has prescribed pretreatment standards for industries discharging to publicly owned treatment works. The permits drafted by EPA and the Massachusetts Division of Water Pollution Control for the MDC Deer and Nut Island treatment plants request development of a sewer use ordinance by July 1, 1976. This ordinance should prohibit introduction into the sewerage system or treatment facilities of any pollutants which:

1. Are toxic according to section 307 (A) of the Federal Act.

2. Create a fire or explosion hazard.

3. Causes corrosive structural damage.

4. Contains solid or viscous substance which could obstruct sewers or interfere with treatment.

5. Are incompatible with treatment according to guidelines established by the Federal Act.

CLARIFICATION OF SECTIONS 3-C AND 4-E
ARTICLE II
USE OF METROPOLITAN SEWERAGE SYSTEM

M.D.C. RULES AND REGULATIONS
COVERING DISCHARGE OF SEWAGE, DRAINAGE, SUBSTANCES OR WASTES

This is intended to assist industries discharging toxic or objectionable metals or non-metals to municipal sewers within the MDC sewer system in interpreting the recintly adopted Rules and Regulations which became effective January 1, 1971.

Toxic or objectionable metals include. but are not limited to, the following:

Antimony	Lead
Arsenic	Manganese
Barium	Mercury
Beryllium	Nickel
Boron	Selenium
Cadmium	Silver
Chromium	Tin
Copper	Zinc
Iron	

Toxic or objectionable non-metals include, but are not limited to:

Cyanides	Sulphides
Phenols	Chlorides

All wastes containing toxic heavy metals must be treated for removal of these metals to values at least equivalent to the minimum solubility of their oxides or hydroxides. Limits for non-metals must be reviewed and approved separately.

Industries discharging or requesting to discharge beryllium, mercury, arsenic or selenium in any quantities are referred to the Division of Water Pollution Control.

The attainment of specific levels for discharge to the public sewer by dilution in the absence of treatment (i.e., by the use of extraneous or other non-process water) is prohibited.

Direct disposal of concentrated plating solutions, whether neutralized or not, shall be prohibited.

Provisions must be made to prevent against accidental or intended discharge.

Sludges, filter cakes, etc., produced by treatment or by naturally occurring deposition in operating baths or tanks, shall not be discharged to the sewer.

A description of the proposed treatment system, including flows of all waste drains and concentrations of toxic or objectionable metals or non-metals before and after treatment must be submitted to the MDC for approval.

6. Have not been subjected to the treatment required by Federal or State law.

The U.S. Environmental Protection Agency, in coordination with the Massachusetts Division of Water Pollution Control regulates direct discharge of industrial waste into the Commonwealths waters through the regulations of the National Pollutant Discharge Elimination System (NPDES) established by the Federal Water Pollution Control Act Amendments of 1972.

Under the National Pollutant Discharge Elimination System, the new national permit program to control discharge of pollutants into the Nation's waters, the U.S. Environmental Protection Agency is required to establish effluent limitations and national performance standards for sources of water pollution, including industries, sewage treatment plants, and animal feed lots.

Industries are required to use "the best practicable" technology to control water pollution by July 1, 1977, and "best available" technology by July 1, 1983. "Best practicable" treatment for a particular industrial category is a balance struck between total cost and effluent reduction benefits. "Best available" treatment is the highest degree of technology proved to be designable for plant scale operation.

Each industry discharging wastes to navigable waters must obtain a permit to discharge. The permit must specify which pollutants may be discharged, and set average and maximum daily limits on discharges, needed to meet effluent standards and limitations, water quality standards, and other State and Federal requirements. Compliance with effluent limits must be achieved by July 1, 1977. The permit also sets interim dates for interim actions and effluent limits.

The source must monitor major discharges. All discharges containing toxic substances for which EPA has limits, whether they are major or not, must also be monitored. The source must also keep monitoring records, and report monitoring data at least once a year.

Even if the regulations of NPDES and the MDC sewer use ordinance are stringent enough to eliminate hazardous discharges, it is still questionable whether existing concentrations of hazardous substances in Harbor sediments can be assimilated or eliminated by natural processes.

e. <u>Stormwater Runoff</u>

In addition to its discharge to combined sewers, stormwater is discharged to the Harbor by drains from streets, land, and parking lots. This run-off contains oil, road salt, dust, dirt, debris and bacteria.

The American Public Works Association, in a study of Chicago stormwater, found that stormwater quality varied with land use; and that stormwater from multiple family dwellings areas contained the largest concentrations of coliform bacteria (9). One can predict large coliform

counts in Boston stormwater as this area contains many apartment complexes and multiple family houses. More information on stormwater run-off is provided in Appendix XI.

f. Oil

Oil is a significant source of pollution in Boston Harbor, especially along the Chelsea River where many oil terminals are located. Harbor spills occur mainly at oil terminals, which are equipped to contain or clean up the spills. Both Massachusetts law as well as the Federal Water Pollution Control Act Amendments of 1972 place liability for spill clean-up costs on the person responsible for the spill.

Another source of oil pollution is its discharge to sewers. Major discharges to sewers are, in most cases, traced to fuel oil losses resulting from failure of tanks, pipes, or mechanical equipment or human error. Oil enters the sewers either by infiltration or directly through a catch basin. Smaller amounts of oil are often accidentally or deliberately discharged to sewers. Businesses discharging waste oil to sewers or surface waters are required to install oil separators and provide for waste oil collection by the municipality, the MDC or the Division of Water Pollution Control. However, substantial quantities of oil still enter the sewer system. It is estimated that 1600-1800 gallons of oil of petroleum origin may be discharged per day by the MDC sewage treatment plants, and it is not known how much is discharged from combined sewer overflows (9).

Waste lube oil is also a growing problem. A study of waste oil disposal practices in Massachusetts, done in 1969 for the Division of Water Pollution Control by A.D. Little, indicates that over 15 million gallons of waste lube oils are generated annually in Massachusetts. An increase in waste lube oil is expected in the future; however, outlets for this oil are shrinking due to a disadvantageous Federal tax situation, labeling requirements, rise in costs to reprocess waste oils, and shrinking markets. Efforts are currently being made by the Massachusetts Division of Water Pollution Control and EPA to reclaim and recycle this oil, and prevent its discharge to the environment.

g. Tributary Streams

The Chelsea, Mystic, Charles, Neponset and Weymouth Fore Rivers enter the harbor in a degraded condition. Combined sewer and stormwater overflows are a major source of pollution to these tributaries. Significant amounts of oil are added to the harbor from the Chelsea, Mystic and Weymouth Fore Rivers, where there is a great amount of shipping activity. The polluted conditions of these tributaries and their effects on public health are discussed in sections on the Charles, Mystic and Neponset Rivers.

h. Refuse and Debris

"The Draft Report on the Debris and Refuse Problem in the Harbor," lists the following sources of debris and refuse in the area (10):

1. Dilapidated shorefront structures

2. Derelict wrecked vessels

3. Dumping from vessels

4. Shoreline dumping

5. Tide, wind and river carried debris from other areas

6. Loose floatable onshore debris

7. Shorefront dumps

8. Storm sewer and combined sewer discharge

The Corps of Engineers studied the debris problem in Boston Harbor in 1968-1969, and found 300 wholly or partially dilapidated structures (totaling 3,251,000 cu. ft.) and 96 derelict wrecked vessels. In addition, the Corps uncovered 73,800 cu. ft. of loose onshore floatable debris. Results of the Corps Debris study are given in Table 10. In 1971, the MDC removed over 3000 tons of solid waste from their beaches. A breakdown of this debris is given in Table 11. Information on specific amounts of other types of debris is not available, although they also contribute significantly to the debris and refuse problem in the Harbor.

The two major adverse effects of the debris and refuse problem are: (1) the severe deterioration of the esthetic qualities of the area, and (2) the hazard to navigation. There are quite a few adverse public health effects related to these two major adverse effects:

1. The Corps of Engineers reports that 4100 recreational craft are based in Boston Harbor, and in 1969, there were 410 reported motor boat drift collisions. Such collisions could cause severe damage or complete loss of craft, personal injury, and loss of life.

2. Refuse and debris dumped in the Harbor can contain toxic chemicals that could affect shellfish.

3. Debris such as large splinters of wood, glass objects, and rusty nails, endanger swimmers.

4. Concentrations of debris provide a refuge for harmful rodents.

5. Finally, a Harbor littered with debris and refuse will encourage further pollution and degradation that may be injurious to the public health.

Current actions are being taken to clean up beaches and eliminate sources of debris. Chapter 878 of the Massachusetts Acts of 1970 give the Massachusetts Department of Public Works, Division of Waterways,

TABLE 10

BOSTON HARBOR DEBRIS STUDY (10)

1968-1969 Visual Examination of Debris Sources
in Boston Harbor, Mass. Conducted by
Corps of Engineers, New England Division

COMMUNITY	TIMBER STRUCTURES			WRECKED VESSELS				
	Number Dilapidated	Number With Portions Dilapidated	Approx. Total Volume (cu.ft.)	Number	Wood	Steel	Volume (cu.ft.)	Loose On Shore Debris-Floatables Approx. Volume
Boston	83	64	2,166,000	51	50	1		29,000
Cambridge	2	1	9,500	0				
Everett	3	1	199,000	1		1		7,500
Revere	3	0	14,000	3	3			3,000
Somerville	1	0	13,000					2,000
Winthrop	7	2	31,000	3	3			1,700
Chelsea	19	13	337,000	4	4		INCOMPLETE	8,400
Quincy	18	2	102,000	8	8			5,000
Braintree	2	0	500					200
Weymouth	8	1	18,000	2	2			1,200
Hingham	12	13	264,500	1		1		3,800
Hull	14	6	39,000	3	3			12,000
Islands	14	2	57,500	20	11	9		Incomplete
TOTALS	186	105	3,251,000	96	84	12		73,800

TABLE 11

SOLID WASTE FROM M.D.C. BOSTON HARBOR RESERVATIONS (10)

1971 SEASON

Reservation	Mixed(2)	Ocean Debris(3)	Total
	SOLID WASTE IN TONS(1)		
Boston Beaches (4)	450	15	465
Wollaston Beach	390	313	703
Georges Island	32	18	50
Peddocks Island	12	23	35
Lynn & Nahant Beach	450	11	461
Revere Beach	1089	10	1099
Winthrop, Short & Constitution Beach	153	8	161
Nantasket Beach	375	305	680
TOTAL (TONS)	2951	703	3654

(1) Quantities were estimated by M.D.C. personnel, not actual weighing results
(2) Mixed Solid Waste - includes picnic refuse, cans, bottles, paper, garbage
(3) Boston Beaches - Castle Island, Pleasure Bay, City Point, Carson, Savin Hill, Malibu, Tenean

the authority to expend a certain portion of unclaimed watercraft gas tax rebates to clean up and maintain the waterways and harbors of the Commonwealth. The main thrust of the Act was to eliminate dilapidated shorefront structures. The Division of Waterways current efforts are as follows:

1. Notify owners to clean up and remove dilapidated shorefront structures.

2. Hire a private contractor to clean waterways and beaches.

3. Remove wrecked vessels and discarded automobiles.

i. Watercraft Wastes

Raw sewage discharged from vessels using the Harbor is also a problem. This untreated sewage is a threat to the public health as waters used for boating are often used for contact recreation.

The Massachusetts Division of Water Pollution Control now has some control over watercraft wastes through Chapter 693 of the Acts of 1970, Section 2, amending Chapter 91 of the General Laws. This law states that that licenses to operate marinas will not be issued unless adequate sanitary waste collection, treatment and disposal facilities are provided for occupants of watercraft, and trash receptacles are provided for garbage and refuse. The law reads as follows:

(Commonwealth of Massachusetts)

LICENSING OF MARINAS. Chapter 693 of the Acts of 1970, Sec. 2, amended Chapter 91 of the General Laws by inserting the following section. It was approved August 18, 1970, but will not take effect until May 15, 1972.

SECTION 59B. No marina shall be operated without a license issued by the Division of Water Pollution Control. Said division shall not issue any such license unless such marina provides (1) adequate facilities for the collection, treatment and disposal of sewage or other sanitary waste, as said division may specify, including facilities for the purging out and cleaning of holding tanks, the contents of which shall be then disposed of in such manner as not to be discharged into or near any waters of the Commonwealth, unless such discharge is to a municipal sewerage system or to an adequate sewage treatment or disposal facility approved by the division of water pollution control: (2) adequate and conveniently located dockside toilet facilities for the use of the occupants of watercraft: and (3) adequate and conveniently located trash receptacles or similar devices designed for the disposal of litter and refuse.

Any license issued under this section shall be for a term of one year and may be renewed annually. The fee for such annual license shall be fifty dollars and the fee for a renewal of such license shall be ten dollars.

The Federal Water Pollution Control Act Amendments of 1972 require the Administrator of the U.S. Environmental Protection Agency to promulgate Federal standards of performance for marine sanitation devices which shall be designed to prevent discharge of untreated or inadequately treated sewage to navigable waters. The Act also specifies that the secretary of the department in which the Coast Guard is operating shall promulgate regulations for design, installation and operation of marine sanitation devices. Initial standards and regulations shall become effective 2 years after promulgation for new vessels and 5 years after promulgation for existing vessels.

A state may prohibit the discharge from all vessels of any sewage, treated or untreated, if it determines that some of its waters need greater environmental protection.

SUMMARY

In 1971, the firm, Hydroscience Inc., contracted by the Massachusetts Division of Water Pollution Control to develop a water quality model for Boston Harbor, studied the effects of individual pollution sources on total coliform bacteria concentrations in the Harbor. It was found that Inner Harbor discharges (including combined sewer overflows), treatment plant sludges, and stormwater overflows were the major sources of bacterial pollution. The Metropolitan District Commission is currently planning to eliminate sludge disposal in the Harbor by incineration of Deer and Nut Island sludge discharges. As yet there are no definite plans for elimination of combined sewer and stormwater overflows as these are quite complex problems requiring a more extensive planning effort.

3. Water Quality Data

Water quality data collected from the Division of Water Pollution Control's 1972 pollution survey of Boston Harbor is presented in Table 12 (11). In general, values of the parameters indicating polluted conditions are highest in the Inner Harbor, and along President Roads and lowest in Quincy Bay. Data on trace metals concentrations in the Harbor's water and sediments, collected for the New England Aquarium's trace metal survey of Boston Harbor, is presented in Table 13 (12). Metals concentrations are, on the whole, higher in the Inner Harbor. The Aquarium found that in the outer Harbor metal concentrations in the water are highest near the Deer Island outfall, and lowest in the southern portion of the Harbor, and in the northern section of Dorchester Bay, as there is less industrial activity in these areas. It was also found that metals concentrations in the sediments of the outer Harbor are highest in the Deer Island Flats area, and in northeastern Dorchester Bay. These areas are deposition sites for the suspended solids emanating from the Deer Island sewage treatment plant, and the Inner Harbor. Metals in the sediments were found to be generally lower in the southern portion of the outer Harbor, again due to less industrial activity.

TABLE 12

WATER QUALITY - BOSTON HARBOR (11)*
(ppm unless otherwise designated)

	1. Inner Harbor	2. President Roads	3. Dorchester Bay	4. Quincy Bay
DO	1.3-12.2	3.6-9.8	3.6-10.4	8.1-9.5
BOD_5	.7-9.2	.3->9	.8->9	2.2-2.7
Ammonia (NH_3-N)	.05-.90	.05-.61	.06-.38	.13-.36
Nitrates (NO_3-N)	0-.2	0	0	0
Total Phosphorus	.08-.86	.06-.88	.06-.30	.10-.13
Alkalinity	37-162	96-177	79-181	101-130
Turbidity (units)	0-27	0.1	0-1	0-1
Color (units)	0-85	0-28	5080	5-12
Suspended Solids	1.0-31	4.0-12.0	3.0-14.0	0-6.0
Total Coliforms	$230-4.6x10^6$	<36-150,000	<36-46,000	<36-91
Fecal Coliforms	$36-1.5x10^6$	<36-93,000	<36-9300	<36-36

Locations are designated in Figure 2.

Water Quality Classifications

Inner Harbor	Class SC
President Roads and Dorchester Bay	Class SB
Quincy Bay	Class SA

*Samples taken for the year 1972

TABLE 13

RANGE OF TRACE METALS CONCENTRATIONS IN BOSTON HARBOR

WATER AND SEDIMENTS (ppm dry weight) (12)*

	Water		Sediments	
	Inner Harbor	Outer Harbor	Inner Harbor	Outer Harbor
Zinc	28.7-67.2	8.3-25.6	445-1230	30-455
Copper	4.5-8.7	2.9-10.2	226-494	4-363
Lead	6.1-17.9	2.5-6.5	161-675	13-347
Nickel	8.8-15.6	4.4-15.4	44-87	8-65
Chromium	1.1-4.2	1.3-6.9	116-174	4-433
Cadmium	.35-.56	.1-1.1	3.3-29	.8-14.9
Cobalt			6.8-17.5	.2-37
Mercury			.92-5.7	.2-6.7
Molybdenum			5.0-14.0	.8-11.4
Vanadium			510-1110	12-181

*Samples taken in 1972

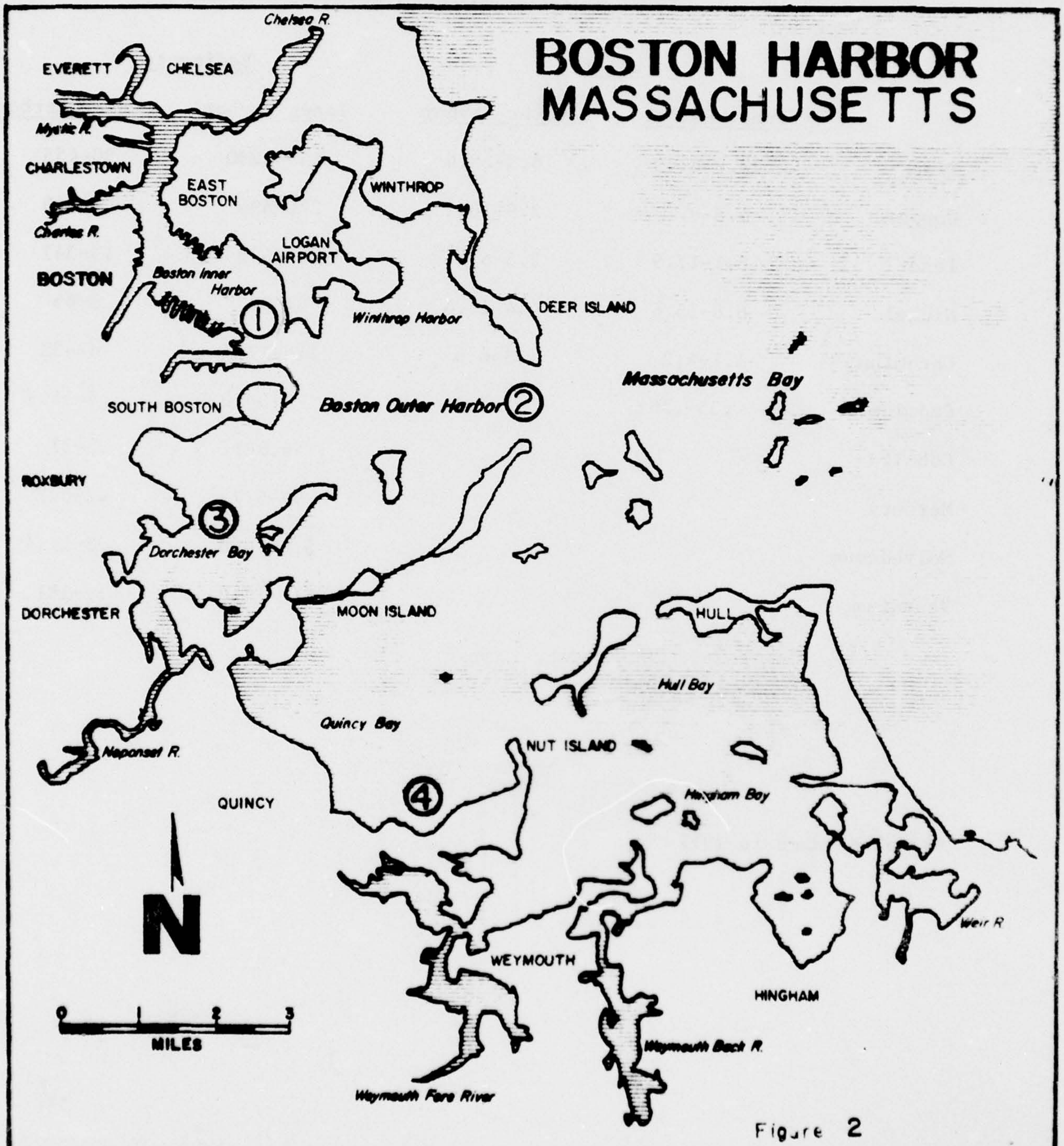

BOSTON HARBOR
MASSACHUSETTS
Chelsea R.
EVERETT
CHELSEA
Mystic R.
CHARLESTOWN
EAST BOSTON
WINTHROP
Charles R.
LOGAN AIRPORT
BOSTON
Boston Inner Harbor
1
Winthrop Harbor
DEER ISLAND
Massachusetts Bay
SOUTH BOSTON
Boston Outer Harbor
2
ROXBURY
3
Dorchester Bay
DORCHESTER
MOON ISLAND
HULL
Hull Bay
Quincy Bay
Neponset R.
NUT ISLAND
QUINCY
4
N
WEYMOUTH
Weir R.
HINGHAM
0 1 2 3
MILES
Weymouth Back R.
Weymouth Fore River

Figure 2

4. Effects of Pollution

a. Bathing Beaches

The bathing beaches of Boston Harbor are a valuable resource to surrounding communities. Conditions at the five Dorchester Bay beaches: Pleasure Bay, L Street, Carson, Malibu and Tenean have been a great concern in recent years due to the conflicting uses of Boston Harbor for recreation and sewage disposal.

Bathing beaches in Boston Harbor are run by the Metropolitan District Commission; however, they are subject to regulations set by the Massachusetts Division of Water Pollution Control, and the Massachusetts Department of Public Health. The Division of Water Pollution Control has given Dorchester Bay an SB classification (suitable for swimming), which requires that a monthly median coliform value of 700 per 100 ml not be exceeded. In addition, the Department of Public Health, according to Article VII, regulation 10, of the State Sanitary Code, has the power to disapprove water for bathing if a significant amount of sewage is discharged to a bathing area, if epidemiological evidence indicates that infectious disease is being spread by the use of a bathing area waters, or if bacterial counts are too high. The Sanitary Code states that coliform counts over 1000 per 100 ml shall indicate a need for further investigation of a bathing area before it can be approved (12).

At many times, coliform counts at the Dorchester Bay beaches are very high due to numerous sources of pollution. Sources of contamination during dry weather are the partially treated effluents discharged at the Deer and Nut Island sewage treatment plants, polluted water from the Inner Harbor, and discharges from ships. In rainy weather, many interceptor sewers overflow releasing large volumes of sewage and stormwater into waters adjacent to beaches.

In 1970, the Massachusetts Department of Public Health released its Survey of Five Dorchester Bay Beaches (13). In this report, it recommended that bathing at Tenean Beach, due to high bacterial counts from combined sewer overflows, be permitted only 3 hours before and after high tide, provided that the rainfall during the previous 24 to 48 hours does not exceed .25 to 1.0 inches, respectively. The Department found the bacterial quality of the water at Malibu, Carson, and L Street to be satisfactory; however, since the water at these beaches was subject to frequent sewage discharge, it recommended that certain actions (such as repair of tidegates) be taken before bathing at these beaches could be approved. Some of these recommendations have been implemented. The water quality at all these beaches has improved since 1970, and they have remained open, and in use. Water in Pleasure Bay was found to be low in bacterial counts, and free of sewage discharge. This beach has also remained open and in use.

Other communities bordering the Harbor, such as Winthrop and Quincy, have bathing beaches which are frequently used in the summer months. At these beaches, bacterial quality of the water is usually

better due to such factors as distances from sewage treatment plants and the Inner Harbor, and lack of combined sewer overflows, and the influx of pure water from the ocean on every tide.

Bathing beaches in the Harbor maintained by the MDC are shown in Figure 3. Water quality classifications set for the Harbor waters by the Division of Water Pollution Control are given in Figure 4.

b. Shellfish Areas

1. Introduction and Background

The shellfish harvesting areas in Boston Harbor are defined by the Mass. Dept. of Public Health as "the waters and flats of Boston Harbor, including all its tributaries inside a line drawn from Windmill Point in Hull to the southeasterly point of Deer Island, and through Deer Island to Point Shirley, and including the shores of Lovell, Gallups and George's Islands." These areas were first classified as shellfish grounds in 1937. As a result of increasing pollution of waters overlying the shellfish harvesting areas in the Harbor, the Mass. Dept. of Public Health has issued orders over the years to prohibit or restrict shellfish digging in the Harbor to protect the public health and welfare. A summary of restrictions from 1937-1974 is given below: (14)

February 13, 1938 - Harvested shellfish from the Slate Island area of Hingham and Weymouth must receive appropriate treatment prior to consumption.

May 5, 1941 - Shellfishing prohibited in Boston Harbor, except for designated areas. As a result,

a. Shellfishing is prohibited in approximately 1,560 acres,

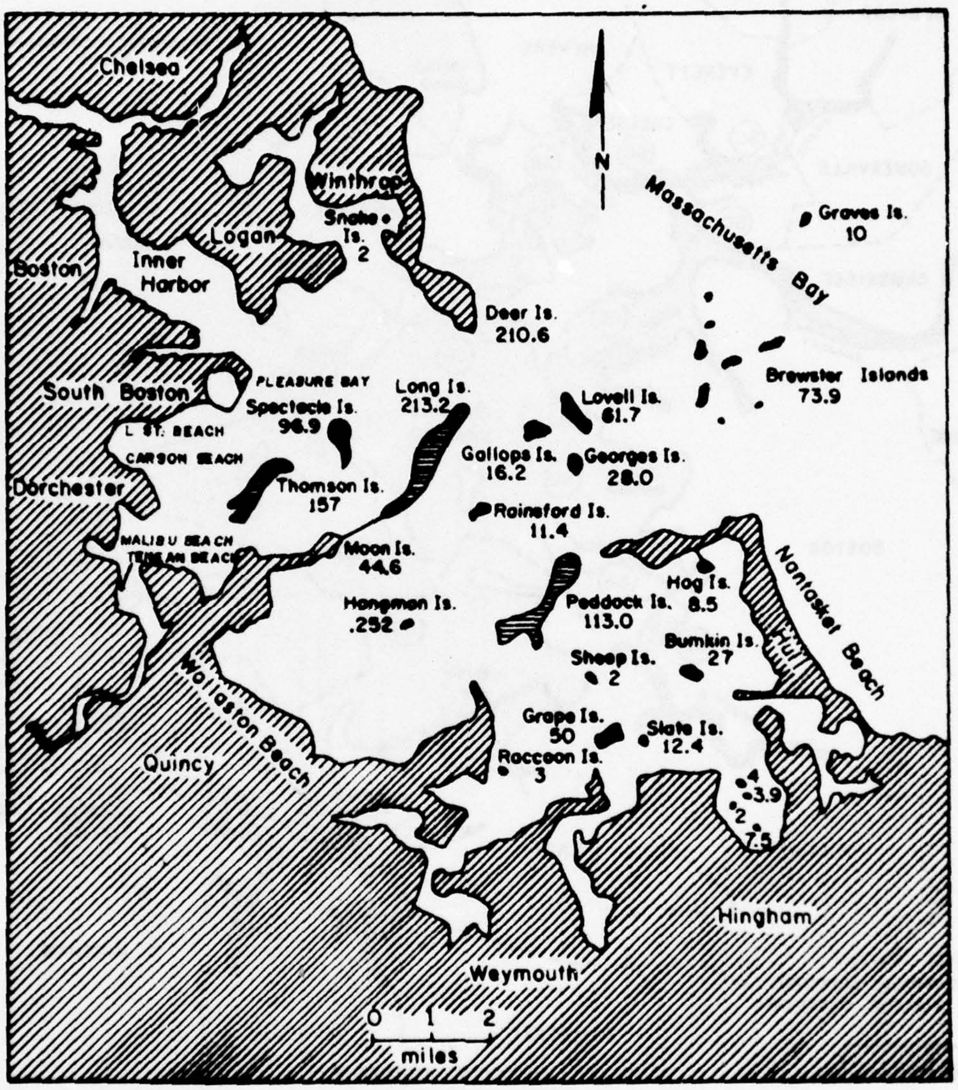
b. Shellfishing is restricted in approximately 2,432 acres, and

c. Shellfishing is unrestricted in in approximately 500 acres.

June 1, 1967 - Shellfishing prohibited in the Old Harbor area. First closure since 1941.

April 1, 1968 - Since June 1, 1967, 1,113 additional acres have been prohibited. As a result,

a. Shellfishing is prohibited in approximately 2,673 acres,



BOSTON HARBOR BEACHES

Figure 3

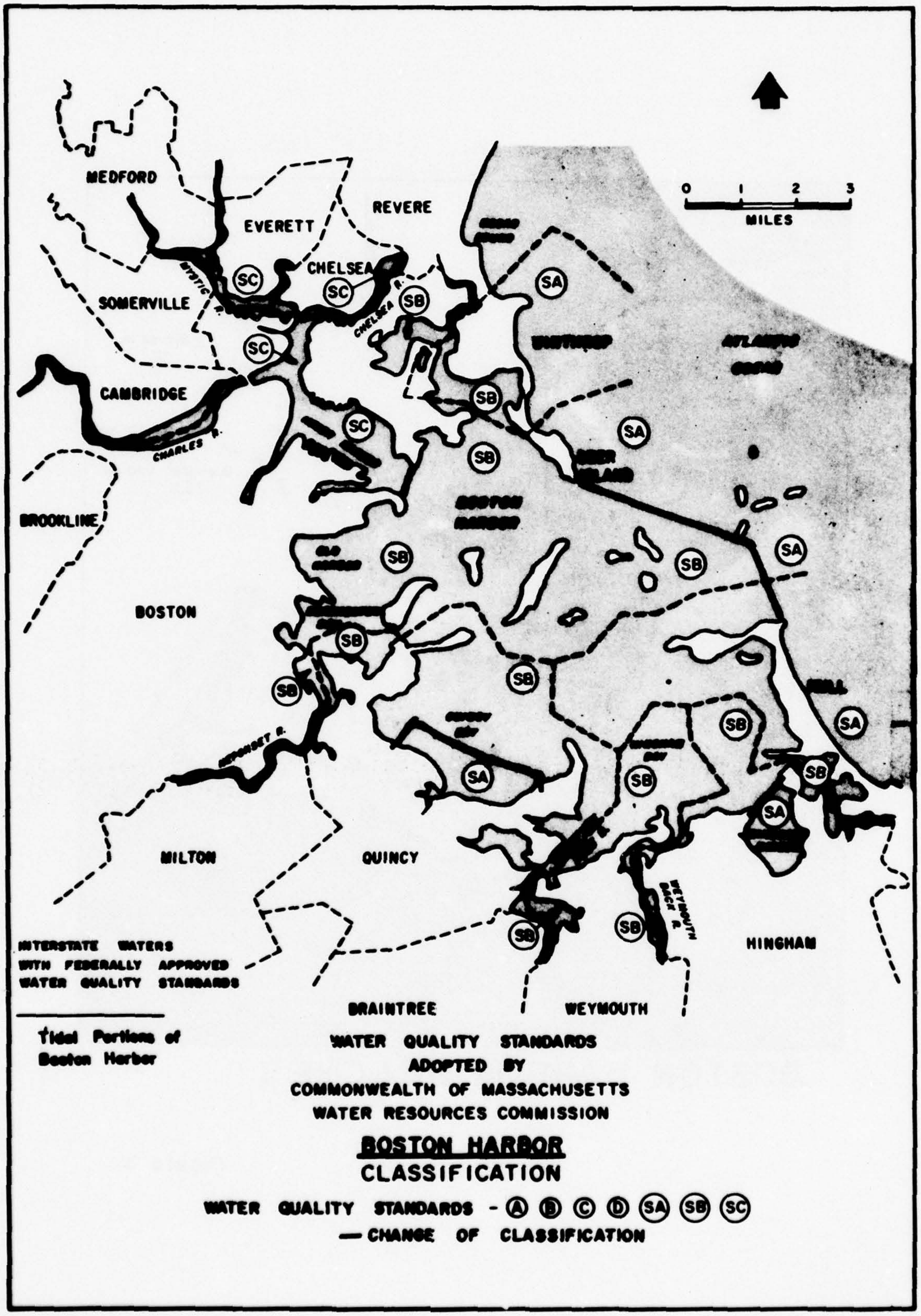

MEDFORD
EVERETT
REVERE
CHELSEA
SOMERVILLE
CAMBRIDGE
CHARLES R.
MYSTIC R.
CHELSEA R.
BROOKLINE
BOSTON
NEPONSET R.
MILTON
QUINCY
BRAINTREE
WEYMOUTH
WEYMOUTH BACK R.
HINGHAM
HULL
0 1 2 3
MILES
SA
SB
SC
INTERSTATE WATERS
WITH FEDERALLY APPROVED
WATER QUALITY STANDARDS
Tidal Portions of
Boston Harbor
WATER QUALITY STANDARDS
ADOPTED BY
COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION
BOSTON HARBOR
CLASSIFICATION
WATER QUALITY STANDARDS - A B C D SA SB SC
— CHANGE OF CLASSIFICATION

FIGURE 4

b. Shellfishing is restricted in approximately 1,319 acres, and

c. Shellfishing is unrestricted in approximately 2,050 acres.

*December 1973 (15) - a. Shellfishing is prohibited in approximately 2,156 acres,

b. Shellfishing is restricted in approximately 2,050 acres, and

c. Shellfishing is unrestricted in 0 acres.

*Acreage difference due to reclassification of areas.

2. Present Shellfish Classifications

Present shellfish harvesting areas in Boston Harbor and their classifications are given in Figure 5. Many of the shellfish areas are closed due to pollution from combined sewage overflows, stormwater runoff, wastewater treatment plants, and vessel discharges. The main basis for these classifications is the total coliform concentrations of the water overlying shellfish beds and an extensive survey of pollution sources in the area. The relationship between these classifications and coliform counts in overlying water is given below:

Prohibited	-	over 700 coliforms/100 ml.
Restricted (must be sent to purification plant)	-	70-700 coliforms/100 ml.
Open	-	0-70 coliforms/100 ml.

Further discussion of the methods of classifying shellfish areas is given in the section, "Methods of Shellfish Control."

The National Shellfish Sanitation Workshop has also proposed "Alert Levels" for various trace metals in shellfish. These levels are not meant to indicate a threat to the public health, as little is known of the mechanisms of metals toxicity in man. The main purpose of these levels is to indicate a change from baseline levels established from shellfish populations not subject to trace metals pollution. Average heavy metals concentrations in tissues of three shellfish species taken from Massachusetts coastal waters are given in Table 14, along with proposed "Alert" levels (40). This data shows that concentrations of certain trace metals in Massachusetts shellfish exceed levels considered hazardous by the workshop.

3. Methods of Shellfish Control

The State of Massachusetts is a member of the National Shellfish

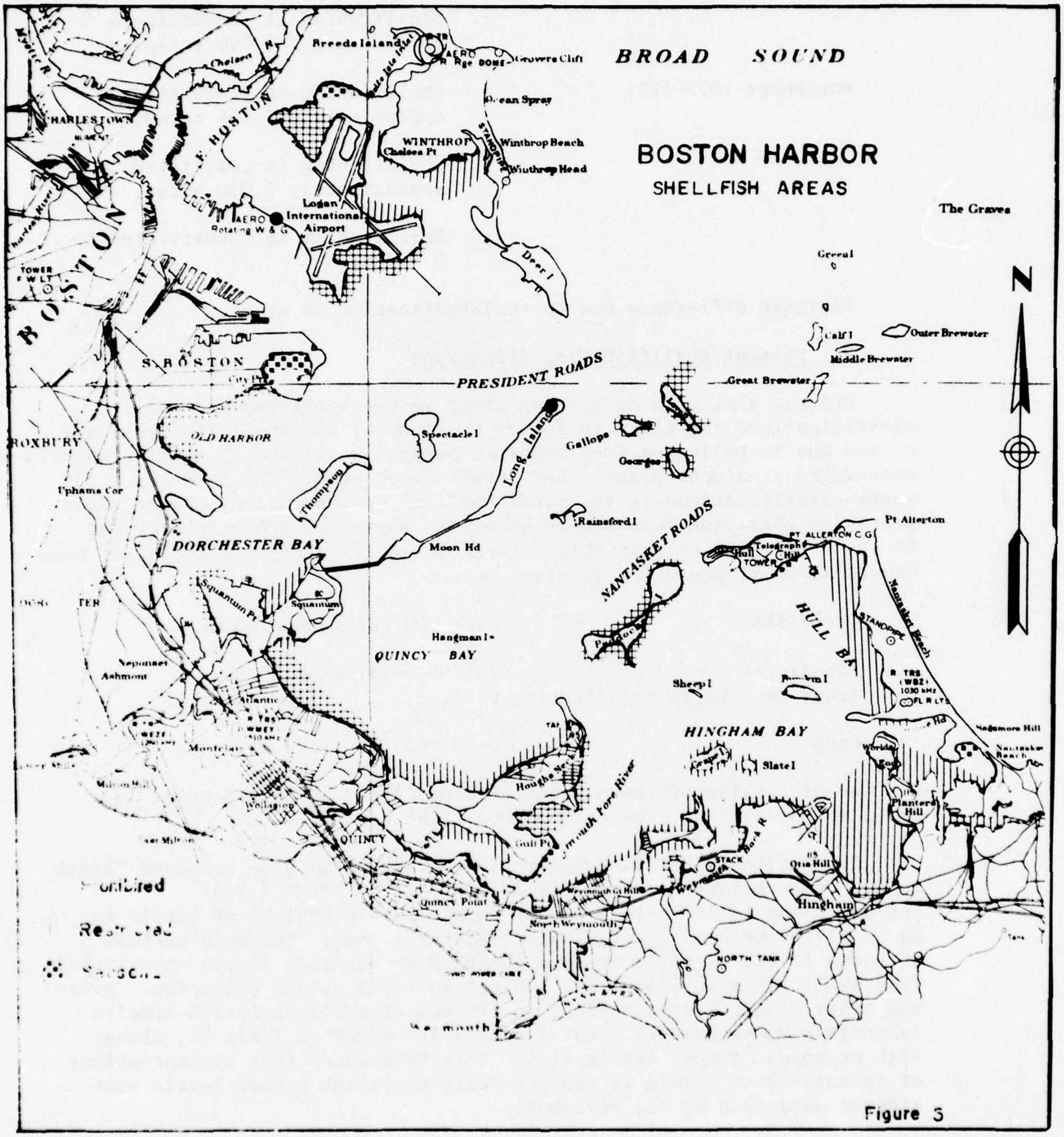

BOSTON HARBOR
SHELLFISH AREAS
BROAD SOUND
The Graves
Breeds Island
Grovers Clift
Ocean Spray
WINTHROP
Chelsea Pt
Winthrop Beach
Winthrop Head
Logan International Airport
CHARLESTOWN
E. BOSTON
BOSTON
Deer I
Calf I
Outer Brewster
Middle Brewster
Great Brewster
S. BOSTON
PRESIDENT ROADS
Spectacle I
Long Island
Gallops
Georges
ROXBURY
OLD HARBOR
Uphams Cor
Thompson
Rainsford I
Pt Allerton
Telegraph Hill
Hull
DORCHESTER BAY
Moon Hd
NANTASKET ROADS
Squantum
Squantum Pt
HULL BAY
Nantasket Beach
Hangman I
QUINCY BAY
Neponset
Ashmont
Sheep I
HINGHAM BAY
Slate I
Montclair
Wollaston
QUINCY
Gull Pt
Quincy Point
North Weymouth
Otis Hill
Hingham
NORTH TANK
Weymouth
Nantasket Beach
N

Figure 5

TABLE 14

AVERAGE TRACE METALS

CONCENTRATIONS IN SHELLFISH

TAKEN FROM MASSACHUSETTS COASTAL WATERS (49)
(ppm, wet weight)

	Oyster		Quohaug		Soft Shell Clam	
Metal	Mean	Alert Level	Mean	Alert Level	Mean	Alert Level
Cadmium	0.78 $\pm$ 0.48	3.5	0.26 $\pm$ 0.31	0.3	0.30 $\pm$ 0.33	0.5
Chromium	0.08 $\pm$ 0.13	2.0	1.2 $\pm$ 0.89	1.0	1.96 $\pm$ 0.71	5.0
Copper	1.31 $\pm$ 0.92	175	7.2 $\pm$ 4.3	10	28.8 $\pm$ 18.5	23
Lead	0.29 $\pm$ 0.13	2.0	1.9 $\pm$ 1.2	4.0	5.45 $\pm$ 8.09	5.0
Mercury			0.30 $\pm$ 0.21	0.2	0.31 $\pm$ 1.06	0.2
Nickel	0.70 $\pm$ 0.29	0.2	2.2 $\pm$ 0.75		3.7 $\pm$ 4.7	
Zinc	747 $\pm$ 449	2000	29 $\pm$ 11	65	34.3 $\pm$ 20.7	30

Sanitation Program for interstate shipping of shellfish, a cooperative partnership between participating states and the U.S. Public Health Service. State agencies involved in this program are:

<u>The Massachusetts Dept. of Public Health</u>

The Massachusetts Dept. of Public Health has the responsibility of classifying and surveying the shellfish areas in Massachusetts according to procedures specified in the "National Shellfish Sanitation Program Manual of Operations, Part 1, Sanitation of Shellfish Growing Areas" (16). The four classifications employed by the Dept. of Public Health are: Approved, Seasonal, Restricted, and Prohibited. The definitions of these classifications are as follows:

<u>Approved</u>: Growing areas may be designated as approved when (a) a sanitary survey indicates that pathogenic micro-organisms, radio-nuclides and/or harmful industrial wastes do not reach the area in dangerous concentrations and (b) this is verified by laboratory findings whenever the sanitary survey indicates a need. The coliform median MPN of the water in approved areas should not exceed 70/100 ml, and not more than 10% of the samples should exceed an MPN of 230/100 ml in portions of the area most likely to be exposed to fecal contamination during the most unfavorable conditions (16). Such an area must also be protected against chance contamination with fecal material, such as temporary breakdown in sewage treatment facilities.

<u>Restricted</u>: "An area may be classified as restricted when the sanitary survey indicates a limited degree of pollution which would make it unsafe to harvest the shellfish for direct marketing...shellfish from such areas may be marketed after purifying or relaying" (16).

The coliform median MPN of the water in restricted areas should not exceed 700/100 ml, and not more than 10% of the samples should exceed an MPN of 2300/100 ml in portions of the area most likely to be exposed to fecal contamination in the most unfavorable conditions. Also the area must not contain harmful concentrations of radio-nuclides and/or harmful industrial wastes.

In Massachusetts, shellfish from restricted areas may be taken only by commercial diggers, and must be sent to a depuration plant in Newburyport, Mass. to be purified before being marketed. The depuration plant in Newburyport is run by the Mass. Division of Marine Fisheries to insure safety to the shellfish consumer. The cost of treating the shellfish is shared by the commercial diggers and the cities and towns from which shellfish are obtained.

<u>Prohibited Areas</u>: "An area shall be classified prohibited if the sanitary survey indicates that dangerous numbers of pathogenic micro-organisms or hazardous concentrations of radio-nuclides and industrial wastes might reach the area. The taking of shellfish from such areas for direct marketing shall be prohibited" (16). Either the median coliform MPN of the water in such an area exceeds 700/100 ml or more than 10% of the samples have an MPN in excess of 2300/100 ml, or the water

in the area contains dangerous concentrations of industrial wastes and radio-nuclides. Actual or potential areas which have not been subjected to sanitary survey shall automatically be classified as "prohibited."

Seasonal Areas: An area is classified as seasonal when it can only be classified as restricted during certain seasons of the year. For example, recreation areas, subject to seasonal pollution from summer houses and boats, may be only open to harvesting from November to April. During the summer months such an area would be classified as prohibited.

A sanitary survey of each shellfish growing area must be performed prior to its approval for shellfish harvesting. The sanitary quality of the area is reappraised every two years, and resurveyed if its quality is thought to be questionable. The "National Shellfish Sanitation Program Manual of Operations" states the purpose of a sanitary survey to identify and evaluate those factors influencing the sanitary quality of a growing area and which may include sources of pollution, potential or actual; the volume of dilution water; the effects of currents, winds and tides in disseminating pollution over the growing areas; the bacterial quality of water and bottom sediments; die out of polluting bacteria in tributaries, and the estuary; bottom configuration; and salinity and turbidity of the water (16).

Since it is difficult because of time and budget limitations to collect a large number of samples from each area, it is recommended that sampling stations be chosen to provide a maximum of data, and to represent as wide an area as possible. It is also recommended that sample collection should be timed to represent the most unfavorable hydrographic and pollution conditions since shellfish respond rapidly to an increase in the number of bacteria and viruses in their environment.

Although the National Shellfish Sanitation Program specifies that shellfish areas are to be classified according to results obtained from both bacteriological and chemical surveys, a heavy emphasis is placed on bacteriological findings. This can be expected, as there are no enforceable limits for concentrations of hazardous industrial wastes and radio-nuclides in shellfish harvesting areas.* However, it is questionable whether the coliform is a reliable indicator of the diverse types of pollution found in the shellfish growing areas of Boston Harbor.

In addition to its duties of classification and surveying of shellfish areas, the Massachusetts Department of Public Health, according to the General Laws relating to Marine Fish and Fisheries, Chapter 130, Section 74A, has the "authority immediately to designate shellfish areas as contaminated, and that shellfish obtained therefrom are unfit for food and dangerous to public health, in the event of an emergency as determined by said department" (17).

*The Massachusetts Department of Public Health has adopted a standard of .5 mg/100 gms mercury in shellfish.

Since shellfish growing areas are reappraised biennially, it is difficult for the Department of Public Health to detect sudden changes in pollutional loads to the areas. However, the depuration plant in Newburyport, Massachusetts continually monitors the final bacteriological quality of each lot of shellfish purified. The plant promptly notifies the Dept. of Public Health if any lot fails to depurate, and the area from which these contaminated shellfish were obtained is designated and closed down. Such a designation is reported the the Director of the Division of Marine Fisheries, and to the Director of the Division of Law Enforcement who take the necessary actions to prevent shellfish harvesting from the area, and to notify local authorities. The closure is in effect until a resurvey is performed by the Dept. of Public Health; such a survey is to be initiated within 30 days after emergency conditions are determined. The area is not reopened to harvesting by the Dept. of Public Health until the water is tested to be within coliform limits for restricted areas, and the sources of pollution have been eliminated. Elimination of the sources of pollution is basically a local responsibility.

Division of Marine Fisheries

Since all shellfish areas within Boston Harbor are classified as restricted or prohibited, they fall under the jurisdiction of the Division of Marine Fisheries, of the Department of Natural Resources. The Division of Marine Fisheries promulgates rules and regulations for issuance of permits to take shellfish from contaminated (restricted) areas. Permits to dig shellfish for human consumption in restricted areas are issued only to Master Diggers and Diggers. A "Master Digger" is "an individual who holds a permit issued under the authority of the General Laws, Chapter 130, Section 75, to dig, or take, or employs others to dig or take shellfish from contaminated areas which have been designated by the Dept. of Public Health as suitable for the taking of shellfish for purification purposes only" (18). A "Digger" is an individual who holds a permit and is employed by a Master Digger. The Division of Marine Fisheries is also responsible for making regulations with regards to legal hours for shellfish digging, transportation from shellfish areas to the depuration plant, records to be kept by the Master Digger, and issuance of permits to shippers, shuckers and reshippers.

The Division of Marine Fisheries also has control of the shellfish depuration plant in Newburyport, Mass., where it requires all shellfish taken from restricted areas to be sent.

The Division of Law Enforcement

The Division of Law Enforcement in the Dept. of Natural Resources has the power to enforce all rules and regulations promulgated by the Division of Marine Fisheries. It employs enforcement officers who continually patrol, by land, 15 designated coastal areas in Massachusetts. It also uses two patrol boats and a helicopter, which are a great aid in patrolling the islands in the Harbor. Officers in the Division of Law Enforcement have the power to apprehend all persons

in violation of the rules and regulations of the Division of Marine Fisheries.

The Food and Drug Administration (FDA)

The FDA of the Federal government is responsible for administering the National Shellfish Sanitation Program. It reviews and accredits all state shellfish programs and it occasionally accompanies investigators from the Mass. Dept. of Public Health on their surveys of shellfish growing areas to assess their techniques. The FDA also annually reviews the files of the Dept. of Public Health to assess their decisions on classification.

B. THE MYSTIC RIVER WATERSHED

1. Description of the Area

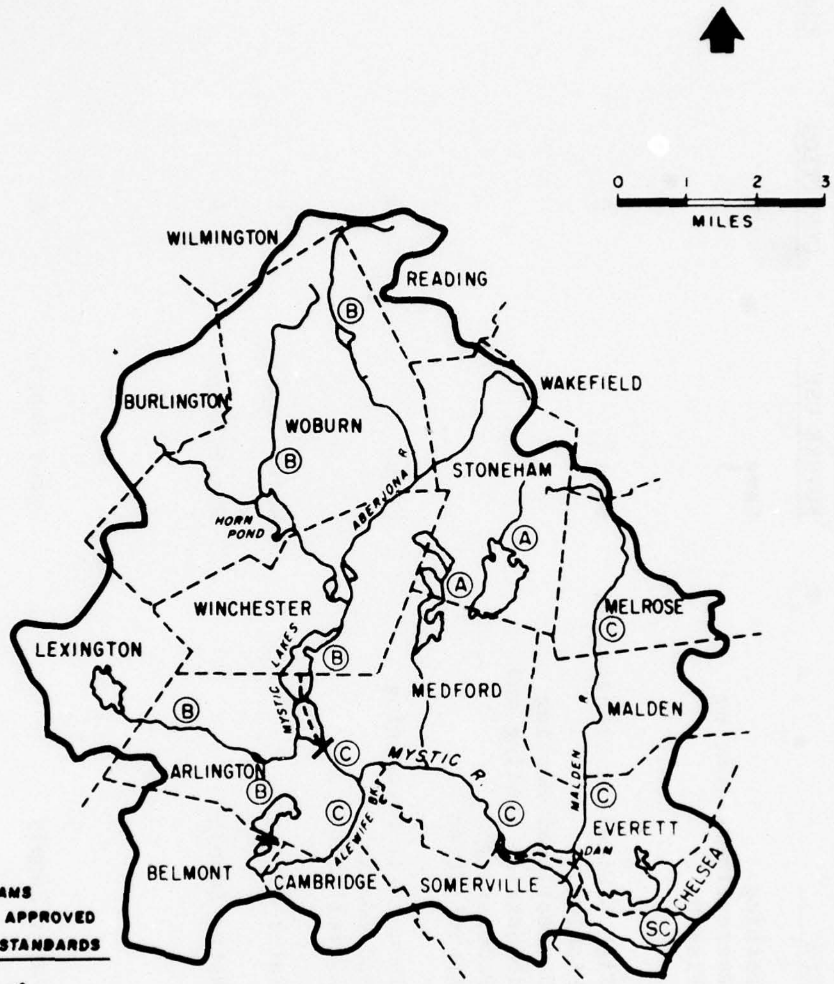
The Mystic River watershed lies north of Boston. It has approximately 69 square miles of drainage area, 23 square miles of which belong to the Aberjona River. The Aberjona River originates in Reading, and runs 8.7 river miles to the Upper Mystic Lake. The overflow from the Upper Mystic Lake forms the Lower Mystic Lake, and the Mystic River begins at the outlet of the Lower Mystic Lake, flowing southward 7.4 river miles to Boston Harbor. Major tributaries to the Mystic are Alewife Brook which enters at the Somerville-Arlington line, and the Malden River which enters at the Medford-Everett line. Most of the towns in this watershed are either urban or suburban in character, and are almost totally served by the MDC's North Metropolitan Sewerage System. Exceptions are Wilmington, where only 1% of the population is served by the MDC, and Burlington, where approximately 50% of the population is served by the MDC. Towns in the lower portion of the watershed are also served by the MDC Water Supply System. Most towns in the upper portion of the watershed are served by water supplies from ground water sources. Woburn, in particular receives its water supply from several wells located near Horn Pond, a tributary to the Aberjona, and along the Aberjona itself. However it is planned that this town will be connected to the MDC water supply system within the next 2 years.

With the exception of the Mystic Lakes, most portions of the Mystic and the Aberjona do not meet the water quality classifications set by the Division of Water Pollution Control. In fact, the Mystic River from the outlet of the Mystic Lakes to Boston Harbor cannot meet the requirements of a Class D river. A map of the Mystic River watershed and its proposed water quality classifications is shown in Fig. 6, and the present condition of various segments of the river and its tributaries is given in Table 15 (19).

2. Sources of Pollution

a. Urban Runoff

Because the communities in the watershed are mainly urban and suburban in character, they contain large areas of impervious pavement. It is quite easy for stormwater to wash pollutants such as oil, grease, salt, and sand from highways and parking lots to nearby waters causing high color, turbidity, and bacteria counts. Urban runoff is a particular problem on the upper portion of the Aberjona, where Routes 128 and 93 are causing high salt and suspended solids content in the water. A sanitary survey made in 1971 found over 53 street and parking lot drains flowing into the Aberjona from its source to the Upper Mystic Lake (20). Urban runoff is also a major problem on portions of the Mystic that run near the Mystic Valley Parkway, on Alewife Brook which runs near Alewife Brook Parkway, and in



INTERSTATE STREAMS WITH FEDERALLY APPROVED WATER QUALITY STANDARDS

Tidal Portion of Mystic River

WATER QUALITY STANDARDS
ADOPTED BY
COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION

MYSTIC RIVER WATERSHED

CLASSIFICATION

WATER QUALITY STANDARDS - Ⓐ Ⓑ Ⓒ Ⓓ (SC)
— CHANGE OF CLASSIFICATION

Figure 6

TABLE 15 (19)

MYSTIC RIVER WATERSHED CLASSIFICATION

BOUNDARY	PRESENT USE	ANTICIPATED FUTURE USE	PRESENT CONDITION	CLASSIFICATION
The Aberjona from its source to the outlet of the Lower Mystic Lake, Arlington-Medford town line	Bathing Recreational Boating Fishing	Same	U	B
The Mystic River from the outlet of the Lower Mystic Lake Arlington-Medford town line to the Mystic River Dam (Amelia Earhart)	Fish & Wildlife Propagation Fishing Recreational Boating Industrial Cooling and Processing Assimilation	Same	D	C
The Malden River	Industrial Processing and Cooling Assimilation	Same	D	C
Horn Pond, Woburn	Water Supply	Water Supply	B	B
North Reservoir Middle Reservoir and South Reservoir, in Winchester, Stoneham, and Medford	Water Supply	Water Supply	A	A
Crystal Lake (treated), Wakefield, Stoneham	Water Supply	Water Supply	A	A
All other streams in the Mystic River Watershed area unless denoted above	--	--	-	B

the estuary where the river is lined with numerous oil tank farms. In addition, many communities in the watershed, as well as the MDC, store road salt along the Mystic and its tributaries. Most communities cover and enclose these salt piles, however. occasional salt pollution of the river system cannot be avoided. Also, the towns of Woburn, Winchester and Arlington often dump snow removed from highways into the Mystic and its tributaries. When this snow melts, large amounts of oil, sand, and salt are released to the water.

b. Oil

The Mystic and the Chelsea Rivers are major commercial waterways with large numbers of oil tanks on their shores. Over 250 oil spills were reported on the Mystic and Chelsea Rivers from the year 1970 to 1973 (21) and it is predicted that this number is only 10% of those that actually occurred. Spills occurred both in the water and on the land, mainly due to equipment failure and personal error. Land spills are equally as hazardous as spills in the water, as the flat land and impervious pavements surrounding tank farms promote rapid runoff of oil into the water.

c. Combined Sewers

The towns of Cambridge, Chelsea, and Somerville are served by combined sewers which overflow into the Mystic and Alewife Brook. Although the Alewife Brook sewer in Cambridge and Somerville was calculated to overflow into Alewife Brook only 9 times during the year 1970, the Somerville-Medford Branch sewer, which overflows into the Mystic, was calculated to overflow at least 72 times during that same year (6).

The cost of separating Somerville's sewers makes such an operation impossible at present. However, proper maintenance of control structures will reduce a large amount of pollution.

The town of Stoneham, which is outside the watershed, is also served by a combined sewer system which often overflows to Sweetwater Brook, a tributary to the Aberjona River at Woburn.

d. Industrial Discharge

In the past both the Mystic and the Aberjona received large quantities of industrial discharge. Today only cooling water and treated runoff from oil companies is discharged to the Mystic. Most industries along the Aberjona and its tributaries are connected up to the MDC sewerage system.

Halls Brook, which flows into the Aberjona River in Woburn, still remains a problem. Here, a drainage ditch flowing along the Boston and Maine Railroad tracks, carries water high in ammonia and acid into the stream. The source of this pollution is a chemical company in Wilmington located on the drainage ditch. Although this company currently discharges its process water to the MDC sewerage system, it does, on occasion, discharge process water to the ditch.

The company's stormwater, which is discharged untreated to the ditch, is a greater problem. For many years process water was discharged to an adjacent swamp, and stormwater flowing through this swamp acquires large quantities of pollutants before flowing to the ditch. The U.S. Environmental Protection Agency is currently in the process of issuing the company a discharge permit to control the quality of stormwater entering the drainage ditch.

Two barrel washing companies located on the drainage ditch flowing to Halls Brook are also degrading water quality. Barrels formerly containing acids, bases and other chemicals are stored open on the ground. Both stormwater and barrel wash water containing chemicals and iron from rusted barrels run to the ditch and leach through the soil to contaminate groundwater.

In addition, another chemical company in Wilmington, using long chain organic chemicals to manufacture resins, inks and coatings is polluting the drainage ditch, as its subsurface disposal system cannot adequately handle this type of chemical waste.

Aside from the Halls Brook area, most industrial pollution in the watershed is related to poor housekeeping practices such as outdoor storage and spillage of chemicals.

e. Landfills

Woburn dump, located on the drainage ditch flowing to Halls Brook, is adding to water quality problems in the area. The dump has been closed, but wastes continue to pollute the ditch and groundwater. High BOD of the groundwater along the drainage ditch has been attributed to wastes lying below the water table.

Arlington dump, which is also closed, is a source of contamination to Reeds Brook which flows to Arlington Reservoir, a recreation area for the town of Arlington.

f. Debris

Rotting piers, and debris on vacant lots are a problem on the Lower Mystic at its confluence with Boston Harbor. A major debris problem also exists on all tributaries to the Mystic, the Aberjona River, and tributaries to the Aberjona. Many citizens groups along the river have implemented clean-up programs. However, results of the clean-up programs are not long lasting, and shopping carts, tires, and junked cars still impede flow in many areas.

g. Salt Water Intrusion

A deep layer of salt water exists in the Mystic River and Lower Mystic Lake due to intrusion of salt water up the River. This salt water on the lake and river bottom leads to the depletion of the waters oxygen supply for two reasons;

1. Salt water cannot hold as much dissolved oxygen as fresh water.

2. Salt water is heavier than fresh water; a combination of salt and fresh water will stratify, inhibiting mixing and aeration.

Low dissolved oxygen is not only hazardous to aquatic life but also leads to the formation of hydrogen sulfide gas, which can rise to the waters surface and cause annoying odor problems.

3. Water Quality Data

Water quality data collected from the water quality surveys made by the Division of Water Pollution Control is presented in Table 16 (19). Concentrations of ammonia and nitrate are quite high in the Aberjona and Mystic Lakes due to industrial discharges on the Aberjona, and various non-point sources such as leachate from landfills and runoff. Coliform counts often exceed the limits for contact recreational use. Values for color turbidity and chlorides are high throughout the basin as a result of runoff from highly urbanized land surrounding the River.

Very little information exists on the metals content of the water in the Mystic River Watershed. The range of concentrations of trace metals in the sediments of the Mystic estuary is given in Table 17 (22).

Low flow is also a water quality problem as it reduces aeration causing unpleasant odors, detracts from the scenery, and increases concentrations of pollutants by providing less dilution water. Low flow is a particular problem along the Aberjona River, especially during the summer and early fall. This is partially caused by the lack of recharge from subsurface disposal systems in the basin; practically all wastewater is diverted out of the basin into Boston Harbor. In addition, some towns and many industries along the Aberjona draw their water supplies from wells located on the river and its tributaries. In 1972, a minimum low flow of .46 cfs occured on the Aberjona many times during the month of October. The average seven day low flow with a ten year occurrence based on 31 years of record for this river is .429 cfs.

4. Effects of Pollution

a. Recreation Areas

The Mystic River is heavily used for non-contact recreation, such as sailing and motor boating. However, coliform counts, which indicate the presence of more dangerous pathogenic organisms, prevent use of the Mystic and Aberjona for swimming.

The Upper Mystic Lake and some lakes and ponds on tributaries, such as Horn Pond, Woburn, and Wedge Pond in Winchester (which is fed by Horn Pond Brook) are open to swimming, but are constantly threatened by numerous sources of pollution.

High nutrient (nitrate and phosphorous) concentrations from various sources of pollution are causing algae blooms especially in

TABLE 16

RANGE OF WATER QUALITY VALUES

IN THE MYSTIC RIVER WATERSHED*
(ppm unless otherwise designated) (19) (22) (11)

	1) Aberjona River		2) Mystic Lakes		3) Mystic River		4) Mystic Estuary	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
D.O.	1.0	12.0	4.7	11.2	2.0	14.7	3.0	12.8
BOD_5	.9	14.0	1.5	5.8	3.6	11.0	2.0	8.2
Ammonia (NH_3-N)	.09	17.0	.18	4.1	.09	2.2	.15	.90
Nitrates (NO_3-N)	.2	25.0	1.0	2.0	.2	1.5	0	.2
Total Phosphorous	.02	.26	.02	.42	.08	.27	.10	.36
Suspended Solids	1	43	3	10	15	35	1	31
Alkalinity	37	99	35	50	33	87	64	118
Coliforms (per 100 ml)	400	95000	100	2200	400	240000	750	240000
Color (units)	55	120	40	70	50	70	10	65
Turbidity (T.U.)	0	13	7	22	18	30	1	27
Chlorides	44	300	90	210	1300	3000	3400	15600

Locations given in Fig. 7

Water Quality Classifications

Aberjona River and Mystic Lakes	Class B
Mystic River and Estuary	Class C and SC

*Sampling dates 6/13 and 8/73

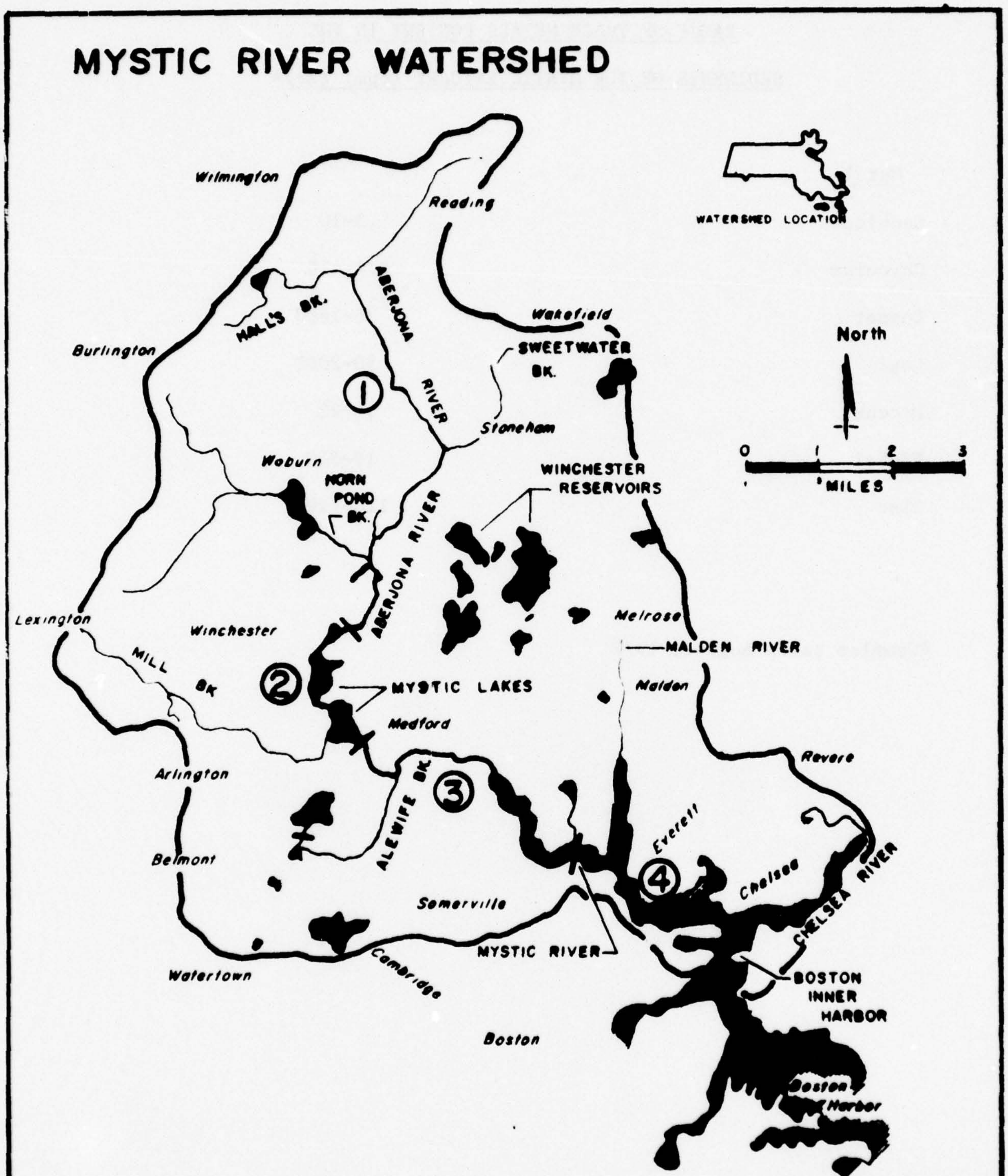

MYSTIC RIVER WATERSHED
Wilmington
Reading
WATERSHED LOCATION
HALL'S BK.
ABERJONA RIVER
Wakefield
SWEETWATER BK.
North
Burlington
Stoneham
0 1 2 3
MILES
Woburn
HORN POND BK.
WINCHESTER RESERVOIRS
ABERJONA RIVER
Lexington
Winchester
Melrose
MALDEN RIVER
MILL BK
MYSTIC LAKES
Malden
Medford
Revere
Arlington
ALEWIFE BK.
Everett
Belmont
Chelsea
CHELSEA RIVER
Somerville
MYSTIC RIVER
Watertown
Cambridge
BOSTON INNER HARBOR
Boston
Boston Harbor

Figure 7

TABLE 17

RANGE OF TRACE METALS CONTENT IN THE

SEDIMENTS OF THE MYSTIC ESTUARY (ppm) (23)*

Metal	
Cadmium	.3-10
Chromium	8.6-410
Copper	36-1600
Lead	30-2000
Mercury	.4-23
Nickel	19-540
Zinc	110-7200

*Samples taken August, 1972

stagnant areas of the river system. When algae are too abundant to be checked by other aquatic organisms, billions of algae live, reproduce and die. When they die, they sink to the river's bottom, adding layers of muck, and depleting the oxygen supply. Depletion of oxygen is further aggravated by a deep layer of salt water on the river bottom. This condition leads to populations of anaerobic bacteria which produce hydrogen sulfide gas as a product of metabolism. Severe odor problems occur when this gas floats to the waters surface. This is a particular problem on the Lower Mystic Lake and the Mystic River, where a deep layer of salt water, decaying algae, and stagnant water cause annoying "rotten egg" odors in the summer, which detract from the recreational potential of the area.

The MDC has studied this problem on Lower Mystic Lake and formerly supported aeration of the lake's bottom. However, this operation may cause the lake to overturn, releasing dangerous concentrations of hydrogen sulfide gas to the air. Recent studies show that some form of slow discharge pumping of the lake's bottom may be the best solution.

b. Shellfish Harvesting Areas

Shellfish harvesting in the Mystic estuary has been prohibited for many years. Today, coliform counts in this area reach as high as 240,000/100 ml. The presence of large concentrations of oil in this portion of the Mystic also makes shellfish harvested from this area both undesirable and hazardous to the consumer.

C. THE NEPONSET RIVER WATERSHED

1. Description of the Area

The Neponset River begins 24 miles southwest of Boston at the outlet of the Neponset Reservoir in Foxborough, and travels 29.5 river miles to its outlet into Dorchester Bay. Two major streams that contribute significantly to its flow are: the East Branch River, which joins the Neponset in Canton, and Mother Brook, a diversion from the Charles River, which joins the Neponset in Dedham. In all, the watershed of the Neponset River and its tributary streams is 121 square miles (not including the drainage area of Mother Brook above Dedham, which belongs to the Charles River). The river flows rapidly in its upper portions, but slows down when it reaches Fowl Meadow, an extensive marshland that borders the river in the Canton-Dedham-Milton area. Sharon is the only town in the watershed which totally employs individual subsurface disposal systems to dispose of its wastewater. The remainder of cities and towns are at least partially served by the MDC South Metropolitan Sewerage System. Towns in the lower portion of the watershed are served by the MDC Water Supply System, while towns in the upper portion are served by groundwater supplies located along the Neponset and its tributaries.

No portion of the Neponset is currently meeting its water quality classification set by the Division of Water Pollution Control (see Fig. 18 and Table 18) (24).

2. Sources of Pollution

a. Industrial Discharges

Most industries along the Neponset River are connected to the MDC sewerage system, and discharge only cooling water to the River. However, in the past, many factories and paper mills discharged their wastes directly to the river, causing high concentrations of organic materials, chemicals, and metals. Many of these pollutants remain, and sludge blankets impede flow in some areas.

b. Combined Sewer Overflow

Combined sewers are a problem at the mouth of the river. Here peak dry weather flows in both the Neponset River Valley Sewer and the Dorchester Interceptor exceed sewer capacity, causing frequent overflow to the estuary (6).

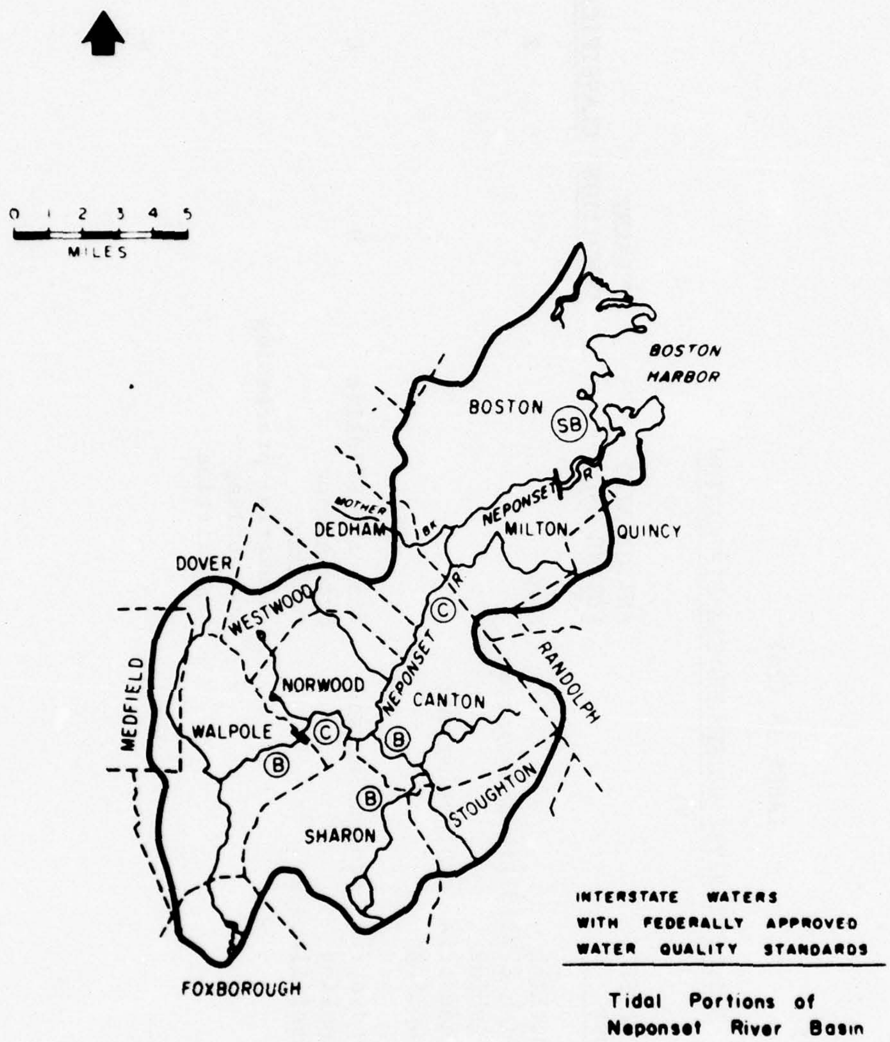
c. Urban Runoff

The cities of Quincy, Milton, and the Dorchester, Roxbury, and Hyde Park sections of Boston are highly urbanized; runoff from streets, parking lots, multiple family dwellings and junkyards located in these communities may contribute significantly to water quality problems in the lower portion of the watershed.

TABLE 18 (24)

NEPONSET RIVER WATERSHED CLASSIFICATION

BOUNDARY	PRESENT USE	ANTICIPATED FUTURE USE	PRESENT CONDITION	CLASSIFICATION
The Neponset River from its source to Washington Street, Walpole	Bathing Fish & Wildlife propagation Fishing Industrial processing and cooling	Same	C	B
The Neponset River from Washington Street, Walpole to Dorchester Ave., Boston	Industrial processing and cooling Assimilation	Fish and Wildlife Propagation Fishing Industrial processing and cooling Assimilation	D	C
All other streams in the Neponset River watershed area unless denoted above	---	---	-	B



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WATER RESOURCES COMMISSION

NEPONSET RIVER WATERSHED

CLASSIFICATION

WATER QUALITY STANDARDS - A B C D SB
— CHANGE OF CLASSIFICATION

Figure 8

Runoff from Routes 128 and 95, recently developed areas, and piles of road salt located at Route 128 station in Dedham, and at the MDC parking facility for the Blue Hills ski area in Milton is a serious threat to the groundwater in the Fowl Meadow area of the river. The towns of Dedham, Westwood and Canton all have water supply wells in the Fowl Meadow area, and the town of Milton is studying the possibility of using groundwater from this area to augment its present MDC supply.

The Fowl Meadow subwatershed is estimated to have 13 billion gallons of water in storage. Present day consumption from the watershed is approximately 1.6 MGD, and the estimated recharge capacity is 5 MGD (25). The aquifer underlying the Fowl Meadow area has three sources of recharge;

1. Percolation of water through the bottom of the Neponset River

2. Percolation of water through the Meadow when the water table is low

3. Percolation of water through porous upland soils.

Polluted runoff water may contaminate the aquifer through all three sources of recharge, and endanger the water supplies taken from the aquifer.

First of all, the Neponset's channel has been widened and deepened in recent years due to erosion and bottom scour from heavier spring runoff caused by development. Because the river's bottom is deeper, the summer water level in the river is lower. Low water levels in the Neponset cause a local depression of the water table in Fowl Meadow. When the water table is depressed, the river will feed water into the water table, and may pollute the aquifer if the river water is polluted by runoff.

Secondly, although peats and mucks in the Meadows are good natural traps for pollutants, rainwater can percolate downward through peats, if the water table is lowered significantly, and pollute groundwater. Also, if the peat dries out and oxidizes due to a lowered water table, its decomposition can release significant quantities of pollutants.

Finally, upland soils are quite porous, and allow rapid infiltration of runoff pollutants to the groundwater.

There has already been an increase in the salt content in every well pumping from the Fowl Meadow aquifer (25). Increased development, particularly of roads, must be checked; and more emphasis must be placed on proper land use management, before the groundwater in the area becomes too polluted for water supply use.

d. Debris

Rotting piers, dilapidated ships and debris from vacant lots

are a problem at the mouth of the Neponset River. Many industrial and construction material junkyards also line the river in its more urban portions.

3. Water Quality

Water quality data collected from the most recent water quality surveys made by the Division of Water Pollution Control, the U.S. Geological Survey and the Boston Transportation Planning Review Report on Fowl Meadow Marsh is given in Table 19 (11) (24) (25) (26). High coliform counts, color, and chloride concentrations which exist on all portions of the River may in part be attributed to high amounts of runoff.

Extensive marshlands, industrial water impoundments, sludge blankets from past industrial discharge, and debris slow down the flow in many areas. In 1972, a low flow of 3.4 cfs was reported on the Neponset at Norwood, and a low flow of 5 cfs was reported on the East Branch in Canton.

4. Effects of Pollution

a. Recreation Areas

The Neponset River itself is not suitable for bathing mainly due to high coliform bacteria counts. Many lakes and ponds in the Basin have acceptable coliform counts and are popular swimming areas.

The MDC has currently acquired $7.9 million for recreational development along the Neponset north of Route 128. Towns and conservation associations along the Neponset are proposing that some of this money be used for land acquisition, clean-up programs and the construction of bikeways and fish ladders. Cleaner river water would enhance the value of the Neponset as a recreational area.

b. Shellfish Harvesting

Shellfish harvesting is prohibited in the Neponset estuary, as coliform counts range as high as 100,000/100 ml.

c. Water Supply

As mentioned in the discussion of urban runoff, the water supply wells for Canton, Dedham and Westwood in the Fowl Meadows area are endangered by polluted runoff from roads, parking lots, salt piles and recent industrial and residential developments.

Water Quality Classifications

Neponset River, source to Walpole - Class B

Neponset River, Walpole to estuary - Class C

TABLE 19*

Range of Water Qualtity Values
in the Neponset River Watershed (11)(24)(25)(26)

	1. Source to Walpole		2. Walpole to Norwood East Branch		3. Norwood East Branch To Estuary		4. Neponset Estuary	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
DO	1.5	14.4	3.4	9.5	4.0	14.0	4.0	7.7
BOD_5	2.0	10.0	1.2	4.0	1.0	4.2	1.0	6.6
Ammonia (NH_3-N)	0	.42	.01	.23	.02	.50	.08	.38
Nitrate (NO_3-N)	0	.5	.2	1.5	.3	1.5	0	.5
Total Phosphorus	.07	.35	.03	.11	.00	.34	0	.15
Alkalinity	19	31	20	34	10	31	21	94
Suspended Solids	1.0	19	1.0	16	1.0	11	1.0	32
Coliforms (per 100 ml)	100	38,000	900	120,000	100	15,000	500	100,000
Color (unit)	10	180	4	110	40	90	22	160
Turbidity (units)	2	4	2	4	10	35	1	11
Chloride	27	42	8	430	48	100	1,600	12,400

Locations are given in Figure 9.

*Samples taken 7/73 and 8/73

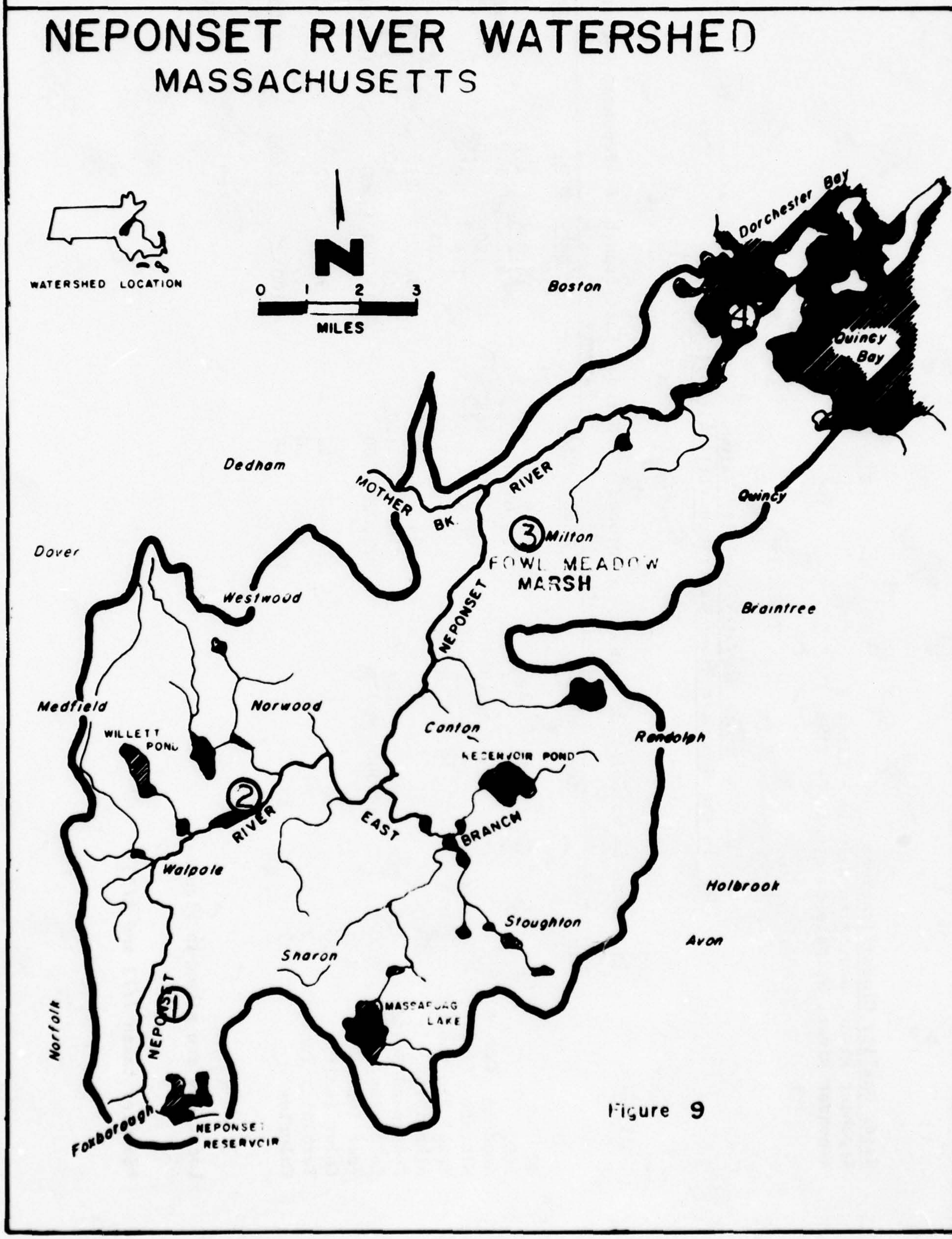

NEPONSET RIVER WATERSHED
MASSACHUSETTS
WATERSHED LOCATION
N
0 1 2 3
MILES
Boston
Dorchester Bay
Quincy Bay
Dedham
MOTHER BK.
RIVER
Quincy
Milton
FOWL MEADOW
MARSH
NEPONSET
Dover
Westwood
Braintree
Medfield
Norwood
WILLETT POND
Canton
Randolph
RESERVOIR POND
RIVER
EAST
BRANCH
Walpole
Holbrook
Stoughton
Avon
Sharon
NEPONSET
Norfolk
LAKE
Foxborough
NEPONSET RESERVOIR

Figure 9

D. THE CHARLES RIVER WATERSHED

1. Description of the Area

The Charles River originates in Hopkinton, 25 miles southwest of Boston. From Hopkinton, the river travels approximately 80 miles, first southward through Milford and Bellingham, and then in a generally northeasterly direction to its outlet in Boston Harbor (27). The Charles River watershed contains over 307 square miles in drainage area, and contains some 33 lakes and ponds as well as numerous tributaries. It has one of the flatest gradients of any stream in Massachusetts with a total drop of 400 feet from its source to the Harbor. The upper portion of the Charles is semi-rural in character, with gently rolling hills and flatlands. The soils in this area, because of their texture and permeability, are subject to minor erosion. Extensive wetlands surround the river as it flows through Millis, Norfolk, and Medfield. As the Charles reaches Dedham, its bordering communities become more urban, and it is surrounded in many areas by pavement from highways, parking lots, and industrial parks.

The watershed area below the Watertown Dam is referred to as the Charles River Basin. This area is densely populated, as it contains only 12% of the land area of the watershed; however, it contains over 70% of its population (28). Here the river is bordered in many areas by parks established by the MDC, and in other areas by impervious pavement of streets and parking lots.

Towns on the lower portion of the Charles are almost totally served by the MDC sewerage system. On the upper Charles, 5 towns Milford, Medway, Franklin, Millis and Medfield, have some form of municipal sewage treatment. The service area of 4 of these facilities is small. In Medway, only 4% of the population is served by a small comminuter and in Millis, Franklin and Medfield approximately 15 to 40% of the population is served by secondary treatment plants. The populations in the remaining towns are served by individual subsurface disposal systems.

The communities on the lower portion of the Charles receive their water supply from the MDC water supply system. The remaining communities rely largely on groundwater supplies, with the exception of Lincoln, whose source is Sandy Pond; Milford, whose source is the Echo Lake at the headwaters of the Charles; and Cambridge, whose source is reservoirs in the Hobbs Brook-Stony Brook sub-watersheds of the Charles River Watershed. Water quality classifications for the Charles and its tributaries, set by the Division of Water Pollution Control, are given in Figure 10 and the present conditions of various segments of the river are given in Table 20. Only the classification set for the Charles from its source to Dilla Street, Milford (Class A) is currently being met (27).

2. Sources of Pollution

Sources of pollution to the upper and lower portions of the Charles

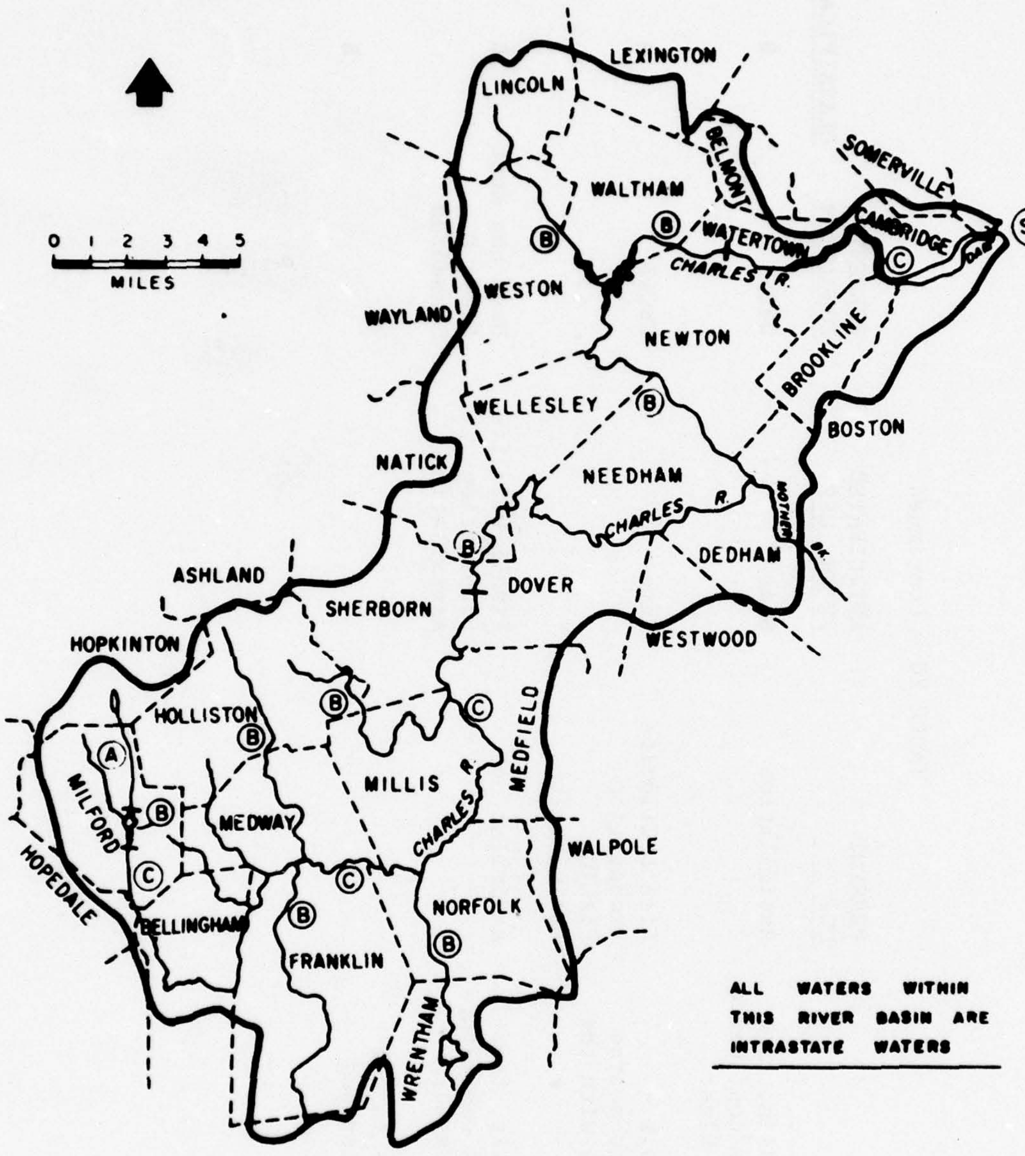
TABLE 20

CHARLES RIVER WATERSHED CLASSIFICATION (27)

BOUNDARY	PRESENT USE	ANTICIPATED FUTURE USE	PRESENT CONDITION	CLASSIFICATION
The Charles River from its source to Dilla St., Milford	Water Supply	Same	A	A
The Charles River from Dilla St., Milford to Main St., Milford	Fish & Wildlife Propagation Fishing	Same & Bathing	D	B
The Charles River from Main St., Milford to Bridge St., Dover	Recreational Boating Fish & Wildlife Propagation Fishing Assimilation	Same	D&C	C
The Charles River from Bridge St., Dover to Watertown Dam, Watertown	Recreational Boating Fish & Wildlife Propagation Fishing Assimilation	Same & Bathing	D&C	B
The Charles River from Watertown Dam, Watertown to Charles River Basin Dam, Boston	Recreational Boating Fish & Wildlife Propagation Fishing Assimilation	Same	D&C	C

TABLE 20 - Continued

BOUNDARY	PRESENT USE	ANTICIPATED FUTURE USE	PRESENT CONDITION	CLASSIFICATION
Mine Brook, Franklin, from its source to its confluence with the Charles River	Assimilation	Same	D&C&B	B
Stop River, Norfolk - Medfield, from its source to its confluence with the Charles River	Fish & Wildlife Propagation Fishing Assimilation	Same	D&C&B	B
Sugar Brook, Millis, from its source to its confluence with the Charles River	Assimilation	Fish & Wildlife Propagation Assimilation	Does not meet Class D Standards	B
All other streams in the Charles River Watershed				B



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WATER RESOURCES COMMISSION

CHARLES RIVER WATERSHED

CLASSIFICATION

WATER QUALITY STANDARDS - A B C D SC

— CHANGE OF CLASSIFICATION

Figure 10

River are different due to differences in the character of the communities in each portion.

Sources of pollution to the upper Charles are:

a. Municipal Sewage

Five towns in the upper portion of the Charles are at least partially served by municipal sewage systems. These systems are described below:

(1) Milford

Ninety-one percent of the town of Milford is served by a secondary treatment plant (trickling filter) which discharges 2.8 MGD to the Charles at river mile 73.4. Although the average flow through this plant does not exceed its design flow of 4 MGD, treatment efficiency is very poor. Due to overloaded settling tanks the effluent is quite turbid, with high concentrations of organic matter, nitrogen compounds, phosphorus and metals from industries in the town. The Charles River at this point is stagnant due to the depletion of oxygen by the wastes, and the presence of algal blooms which are stimulated by high concentrations of phosphorus and nitrogen. Sludge worms abound on the river bottom.

(2) Franklin

Approximately 40% of the town of Franklin is served by a secondary treatment plant (trickling filter) which discharges 1.6 MGD to Mine Brook, which flows into the Charles at river mile 63.2. Removal efficiency at this plant is poor as its average flow exceeds design flow, and its filters are becoming overloaded. In addition treatment is often impaired by textile wastes in the influent. Both Mine Brook and the Charles below the Franklin waste treatment plant are very low in dissolved oxygen content, again due to high concentrations of organic compounds from the treatment plant effluent, and algal blooms which have resulted from high nitrogen and phosphorus concentrations in the effluent.

(3) Medway

The town of Medway has a sewerage system which serves approximately 4% of the population. Wastes collected by this system are run through a comminuter, chlorinated, and then discharged to Great Black Swamp at approximately river mile 63. The low grade treatment of this waste and the location of the discharge near the Franklin sewage treatment plant serves to further degrade the quality of the water in this area. Franklin and Medway have formed the Charles River Pollution Control District, and are currently working on plans for a regional plant to be completed in 1979. The plant is to be located 1/2 mile north-northwest of Lake Populatic with the outfall below the Lake at river mile 58.7.

(4) Millis

The town of Millis is served by a secondary treatment plant (extended aeration). This plant serves approximately 20% of the town's population, and discharges approximately .3 MGD of wastes to Sugar Brook flowing into the Charles at river mile 49.8. Efficiency of treatment is impaired because the flow through the plant often exceeds its design capacity. Until recently, two industries in the town overloaded the system to the extent that the wastewater received almost no treatment. These industries are no longer using the treatment plant, and treatment efficiency has improved. However, the plant still does not achieve sufficient removal of such pollutants as organic matter and nutrients, which degrade the water quality.

(5) Medfield

The town of Medfield is served by a secondary treatment plant (extended aeration). This plant serves over 15% of the population and discharges approximately .4 MGD to the Charles River at river mile 49.2. Again, treatment is not efficient enough to remove oxygen demanding wastes and nutrients such as phosphorus which create algal growth and stagnant, odorous conditions in the water. Medfield is currently constructing an advanced wastewater treatment plant, scheduled for completion by December 1974.

(6) State Institutions

Besides these municipal sewage treatment plants, four institutions in this portion of the watershed discharge partially treated sanitary wastes to the Charles and its tributaries. These institutions are listed below:

(a) Wrentham State School discharges .14 MGD into Stony Brook, Wrentham, a tributary to the Stop River, which joins the Charles at river mile 51.8.

(b) Pondville Hospital in Norfolk discharges .054 MGD to the Stop River.

(c) Norfolk Prison discharges .3 MGD to the Stop River.

(d) Medfield State Hospital discharges .3 MGD to the Charles River at river mile 47.5.

Effluents from Norfolk Prison and Medfield State are presently of poor quality. However, Norfolk is currently building a new secondary treatment plant, and Medfield State plans to connect to the new Medfield advanced treatment plant. Pondville Hospital and Wrentham State discharge fairly high quality effluents. However the secondary treatment provided at these institutions is still not adequate to remove the nutrients which promote algal blooms.

Over a 25 mile stretch of the Charles, nine treatment plants discharge their wastes. Algal growths are quite dense in many areas of this portion of the river. These growths are a particular problem during periods of low flow when the oxygen content of the river is depleted, and the river becomes stagnant and odorous.

b. Solid Waste Disposal Sites

Sixteen communities along the Charles have improperly operated solid waste disposal sites whose leachates and debris pollute the Charles, its tributaries, and water supplies in the watershed. Some of these sites have been closed, but their leachates and debris continue to pollute surface and ground water. They are listed below with the body of water they pollute.

Disposal Site	Body of Water
1. Milford - closed	Charles River
2. Holliston	Swamp Near Hopping Brook
3. Franklin	Mine Brook
4. Medway	Water Supply Well
5. Millis	Swamp Near Charles River
6. Norfolk	Stop River
7. Medfield	Charles River
8. Weston	Water Supply Wells
9. Wellesley	Swamp Near Indian Brook
10. Natick	Indian Brook
11. Needham	Swamp Near Mother Brook
12. Dedham	Mother Brook
13. Waltham - closed	Charles River
14. Lincoln	Watershed of Hobbs Brook Reservoir
15. Newton	Purgatory Cove
16. West Roxbury	Sawmill Brook

c. Subsurface Disposal

A large percentage of the population in the upper Charles is served by individual subsurface disposal systems. In the town of Medway which has particularly poor soils for this type of treatment, approximately 97% of the population is served by such individual systems. Pollution from malfunctioning subsurface disposal systems is also a problem in Norfolk on Lake Populatic where overloaded systems from summer residences cause high concentrations of organic matter, nutrients, and bacteria in the water.

d. Industry

Today most industrial discharges to the lower Charles are cooling water discharges. In the upper portion of the Charles watershed problems involving the discharge of industrial process water still exist. An aluminum can company and a bottling company are discharging process water high in metals, BOD, coliforms, and other pollutants to

Sugar Brook in Millis. These industries were formerly connected to the Millis wastewater treatment plant, which discharges to the same brook; however their effluent greatly impaired the efficiency of the plant. These industries were forced to disconnect; and they now discharge wastes directly to the stream. EPA is presently drafting discharge permits for both industries. The can company, which discharges sanitary wastes along with its process water has a pretreatment system, but it is inefficient in removing its hazardous wastes. With improved and expanded treatment facilities the industry may be allowed to reconnect with the Millis treatment plant. The bottling company which is discharging untreated sugar waste, high in BOD, will have to implement some form of treatment, as the Millis treatment plant cannot handle this industry's waste.

e. Urban Runoff

Although the Upper Charles is not urban in character, it is polluted in many areas by stormwater carrying large amounts of sand, gravel, salt and oil from paved surfaces. In Milford, the river runs through the heart of an industrial complex. In Dedham, the river flows along Route 1 to Needham and Newton where it receives runoff from the paved areas of industrial complexes. In Waltham, again the river passes through many industrialized paved areas. All these areas contribute to the high values of turbidity and suspended solids in the water.

The major sources on the Lower Charles Basin are:

(1) Combined Sewer Overflows

Many of the cities in the Lower Charles Basin are served by combined sewer systems. In periods of rainfall, these sewers overflow to the Charles and its tributaries adding heavy concentrations of coliform bacteria, oxygen demanding wastes, and nutrients to the receiving waters. Major combined sewer systems overflowing to the Charles and its tributaries are listed below (50);

(a) The MDC Charles River Valley sewer intercepts flows from Waltham, Newton, Watertown, Brookline and Boston along the south bank of the Charles as far as Boston University Bridge before it turns in a southeasterly direction to the Ward Street pumping station.

(b) The MDC South Charles Relief sewer originates at the Waltham-Newton line, and parallels the Charles River Valley sewer to the Boston University Bridge, where flows in excess of 117 cfs are treated by the Cottage Farm Detention and Chlorination Station. This sewer was constructed to receive all overflows from the Charles River Valley sewer, and to carry five year storm flow, i.e. flow of stormwater and sewage that occurs on an average of once in five years. If the design capacity of the sewer is exceeded, overflows occur on the Charles above B.U. bridge.

The Cottage Farm Detention and Chlorination Facility, located near B.U. bridge, receives overflows from the North Charles Relief sewer and the South Charles Relief sewer. It is designed for a five

year storm flow 233 MGD. Here the bacterial concentrations of the combined sewer overflows are reduced by disinfection prior to their disposal in the Charles. This facility was activated 34 times to treat overflows during the fiscal year 1973 (3).

(c) The Brookline sewer empties into the Charles River Valley sewer and the South Charles Relief sewer downstream of the Cottage Farm Station. Overflows from this sewer occur on the Charles and the Muddy River, which flows to the Charles.

(d) The MDC Boston Marginal Conduit receives overflow from the West Side Interceptor and the Foul Flow Conduits of the Stony Brook System as it flows along the south bank of the Charles River to the Charles River Dam. Overflows from this conduit occur both to the Charles above the dam, and to its tidewater. At present, due to salt water infiltration, the Boston Marginal Conduit overflows to the Basin at each high tide. The MDC is presently completing the final design for a Detention and Chlorination Station to treat all combined sewage overflows from the Boston Marginal Conduit, the Cambridge Marginal Conduit, and 4 other sources not tributary to the Charles River Basin.

(e) The Stony Brook sewer carries wastes and stormwater from Hyde Park, West Roxbury, Dorchester, Roxbury, Brookline and portions of Back Bay. Forty four percent of the combined sewer area which overflows to the Charles is served by this interceptor (28). Overflows from this sewer occur to the Back Bay Fens before the flow reaches the Boston Marginal Conduit.

(f) The MDC Cambridge Branch sewer runs from the Cambridge Belmont line, along the north bank of the Charles to Boston University Bridge where it flows into the North Charles Relief Sewer. Another section of the sewer extends from B.U. Bridge to Main Street, Cambridge. This sewer has 17 outlets to the Charles, and it was calculated to overflow 45 times during the year 1970 (6).

(g) The North Charles Relief Sewer has been constructed by the MDC to collect overflows from the North Charles Metropolitan Sewer. Flows in excess of 69 cfs are treated at the Cottage Farm Detention and Chlorination Facility. Flows up to 69 cfs are carried to the Deer Island Treatment Plant via the Ward Street Headworks.

(2) Urban Runoff

The Corps of Engineers has estimated that approximately 90% of the flood peaks in the Charles River Watershed originate within the lower Basin which represents 12% of the total drainage area of the watershed (29). Higher runoff from the lower basin may be attributed to its large areas of impervious ground surface from which rains can easily carry oil, grease and sand, as well as bacteria into the river.

(3) Salt Water Intrusion

Today, sea water intrudes the Basin adding to the layer of

salt water at the bottom of the basin which has existed since the construction of the Charles River Dam in 1910. This salt water stratification creates low dissolved oxygen on the river bottom which leads to large populations of anaerobic bacteria that use the sulfates in the salt water to produce hydrogen sulfide gas. The bottom muds in the lower basin have been described as black oozy muds, high in hydrogen sulfide, that emit foul odors. The U.S. Army Corps of Engineers is presently constructing a new Charles River Dam, and had plans to install pumps that would pump out the deep layer of salt water. These plans have been delayed as recent studies show that the pumping operation may release hazardous concentrations of hydrogen sulfide gas.

3. Water Quality

Water quality data collected from recent reports published by the Division of Water Pollution Control, and river surveys performed by the Charles River Watershed Association is presented in Table 21. High concentrations of ammonia, nitrates and phosphorous in the upper portion of the river indicate the effects of inadequate treatment of sewage, as well as non-point sources. Coliform counts are high in all portions of the river and particularly in the Basin due to combined sewer overflow and urban runoff. Table 22 presents water quality data for two tributaries to the upper Charles which are heavily polluted by treatment plant effluents. Very little data exists on metals concentrations in the Charles River. Ranges of heavy metals concentrations in two brooks tributary to the Charles were measured by U.S.G.S. in 1971. This data is presented in Table 23 (31). Low flow is also a problem on the upper Charles especially during the summer months. Although the average flow at Charles River Village in Needham for 31 years of record is 293 cfs, the average seven day low flow with a ten year recurrence level at this location is 12 cfs. At Waltham, an average seven day low flow with a ten year recurrence of 4 cfs has been recorded. Low flow is partially caused because the towns of Dedham, Needham, and Wellesley draw their water supplies from groundwater in the basin, and yet their wastes are disposed through the MDC sewerage system to Boston Harbor. Also, the entire runoff from the Stony Brook sub-watershed which lies in the towns of Lincoln, Lexington, Weston and Waltham is diverted to reservoirs that serve as a water supply to the city of Cambridge. Low flow conditions are not only unsightly, but they give rise to higher concentrations of pollutants due to lack of dilution water.

4. Effect of Pollution

a. Recreation Areas

The Charles River was once lined by many beaches as far downstream as the location of Massachusetts General Hospital. It has been 20 years since the last public beach directly on the Charles was closed in Natick due to high bacterial counts, turbidity, and algal blooms. Today only a few lakes (including Farm Pond, Sherborn, Morses Pond, Wellesley and Nonesuch Pond, Weston) are open to swimming, yet the Div. of Water Pollution Control has set a water quality goal of Class B

TABLE 21

Range Of Water Quality Values In The Charles River Watershed (27) (30) (11)*
(ppm unless otherwise designated)

	1 Charles R. from Dilla St. Milford to Dover		2 Charles R. from Dover to Watertown Dam		3 Charles R. from Watertown Dam to Boston Harbor	
	Min.	Max.	Min.	Max.	Min.	Max.
DO	0.3	16.2	3.6	12.6	3.8	9.9
BOD_5	1.2	12	2.6	10.0	1.5	6.6
Ammonia (NH_3-N)	.02	6.9	.01	.29	.08	.53
Nitrate (NO_3-N)	0	2.7	0	1.0	0	.4
Total Phosphorous	.02	5.0	.14	.50	.30	1.4
Alkalinity	8	78	17	32	25	90
Suspended solids	1	59	1	57	1	32
Turbidity (T.Ul)	1	9.2	3.2	10.6	1	8.5
Color (units)	68	142	128	184	28	156
Chlorides	29	76	49	70	99	10600
Total Coliforms	200	180,000	400	150,000	200	2.4×10^6
Fecal Coliforms	-	-	-	-	430	240000

Locations given in Figure 12

Water Quality Classifications
Charles River, Milford to Dover - Class C
Charles River, Dover to Watertown Dam - Class B
Charles River, Watertown Dam to Boston Harbor - Class C

*Sampling dates 6/73 and 9/73

CHARLES RIVER WATERSHED

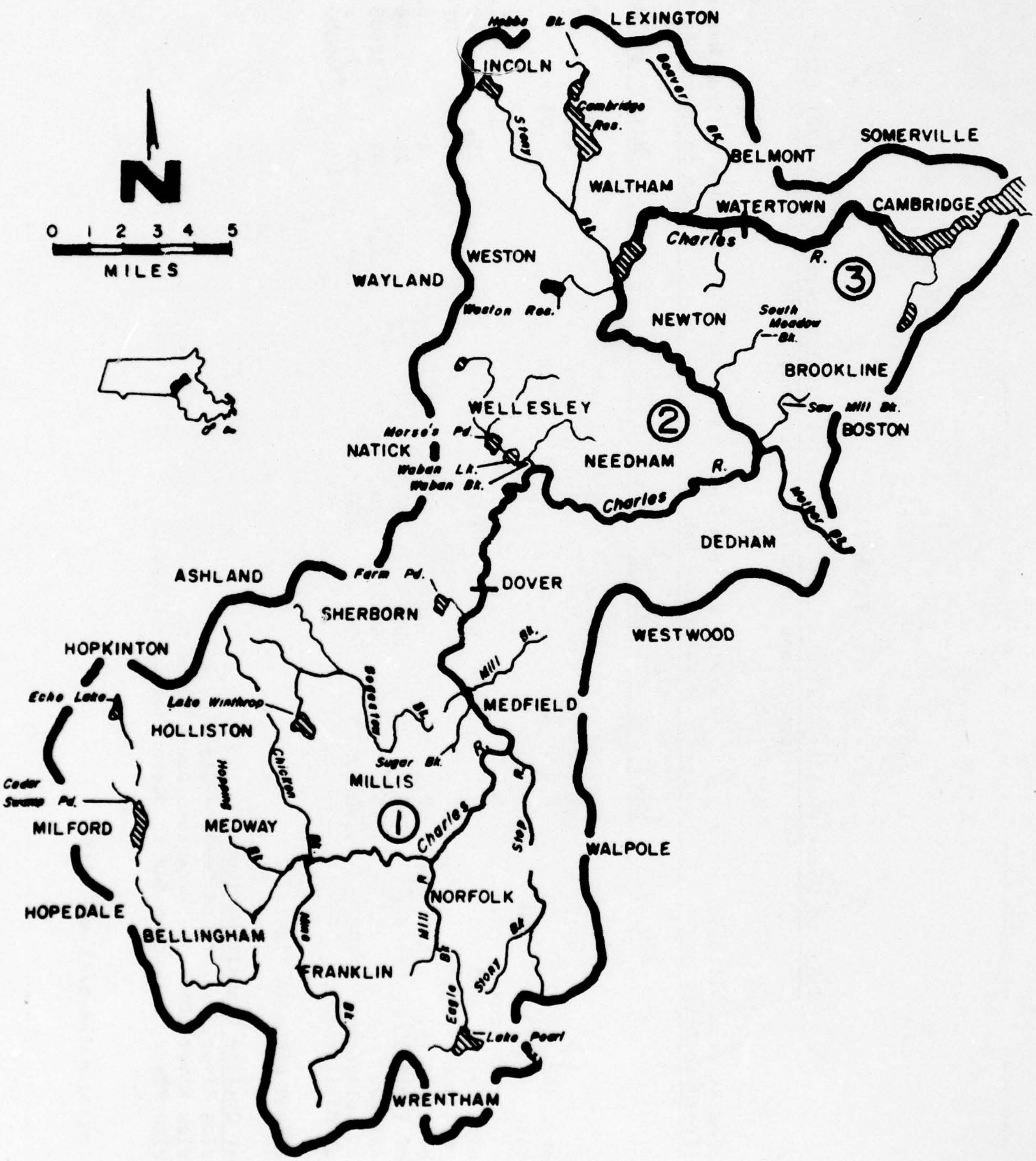


Figure 11

TABLE 22

Range Of Water Quality Values On Mine Brook And Stop River (27)*

(ppm unless otherwise designated)

	Mine Brook		Stop River	
	Min.	Max.	Min.	Max.
DO	0.4	8.8	2.4	8.6
BOD_5	1.2	10	1.2	6.0
Ammonia (NH_3-N)	.06	4.8	.04	.29
Nitrate (NO_3-N)	.1	.3	0	.6
Total Phosporous	.06	2.40	.20	2.30
Alkalinity	16	51	13	63
Suspended Solids	1.0	47	1.0	40
Total Coliforms	1,800	2.6×10^6	200	85,000

Locations given in Figure 11

Water Quality Classifications

Class B

*Sampling dates 6/73 and 9/73

TABLE 23

Range of Heavy Metals Concentrations in Charles River Tributaries (ppb) (31) *
(Jar Brook, Holliston and Bogastow Brook, Millis)

Arsenic	0
Chromium (Cr+6)	2-7
Copper	0-30
Mercury	
Lead	2-7
Nickel	2-4
Zinc	0-20

*Samples taken in 1971

(swimming) for the entire area of the river extending from Dover to the Watertown Dam.

Algal growth and hydrogen sulfide fumes make non-contact recreation unpleasant in many areas, and high coliform counts in the lower Basin make boating almost hazardous.

b. Shellfish Harvesting

Shellfish harvesting in the Charles estuary has long been prohibited, as coliform counts sometimes measure in the millions in this area due to many upstream sources of pollution.

E. THE SOUTH COASTAL - NORTH RIVER WATERSHED

1. Description of the Area

The South Coastal Region extends from Hull at the easterly end of Boston Harbor, southward to the town of Duxbury. The most important stream running through this region is the North River. The North River is a tidal stream which meanders through the salt marshes of Scituate, Marshfield, Norwell, Pembroke, and Hanover. Today, it is a fairly clean river compared to many years ago when it was a center for shipbuilding, tanneries, and iron works. It is an excellent fishery and its salt marshes abound with many types of ducks (32).

Although the North River itself is fairly clean, its tributaries have become quite polluted by domestic wastes from both subsurface disposal units and municipal wastes. One such tributary is French Stream, which originates in Weymouth and flows through Abington and Rockland to join the Drinkwater River at the Hanover line. The Drinkwater River flows in a southeasterly direction to form the Indian Head River after flowing through Factory Pond on the Hanover-Hanson line. Discharges of waste into French Stream have caused an overabundance of nutrients in ponds intercepted by both French Stream and the Drinkwater River. Plant growth in these ponds has already led to their abandonment as swimming areas.

The Indian Head River forms the southern boundary of Hanover. It is quite a clean river, and quite a charming place to fish and swim. A mile and a half downstream lies a dam at Curtis Crossing, where the Indian Head River becomes the North River. From here, the North River meanders through woods and salt marshes to the ocean in Scituate. Its largest tributary is the South River which flows northeast from Duxbury, entering the North River at Humarock Beach, Marshfield. The total drainage area of this basin covers 123 square miles (32).

The towns in this area are not densely populated, although population does rise in the summer months in coastal towns, and rapid growth is projected for towns such as Norwell and Pembroke.

Sewage is disposed by means of subsurface disposal in a major portion of this region. Rockland does have a secondary treatment plant on French Stream that serves 20% of its population. Five percent of the town of Cohasset is served by a secondary treatment plant and 10% of Scituate is served by a secondary plant with sand filtration. Marshfield has a primary treatment plant which serves only 2% of the population.

Hull has 5 isolated collection systems which discharge raw waste to Hull Bay, however, the town is currently planning to build a secondary treatment facility.

As for water supply, all towns are served by both municipal groundwater and surface supplies. Water quality classifications set by the

Division of Water Pollution Control for both the North River and the South Coastal area are given in Figure 12. Presently, the upper portions of the North River and harbors along the coast are not meeting these classifications.

2. Sources of Pollution

This region has fewer pollution problems than other watersheds in the study area, as it is less densely populated, and contains very few industries.

For the most part, pollution problems arise from the intense use of waters in summer months. The major sources of pollution are:

a. Municipal Sewage

Municipal sewage is a major source of pollution in the ocean waters surrounding Hull, as wastes from this town's collection system are discharged without treatment.

Effluents from the Rockland sewage treatment plant flow to French Stream. Although the effluent receives secondary treatment, it is very high in suspended solids, BOD, and nutrients, and is the major cause of algal blooms in this section of the North River Watershed.

Effluents from the Cohasset and Scituate treatment plants are fairly good, and cause only minor problems to their receiving waters.

b. Subsurface Disposal

Malfunctioning subsurface disposal units pollute parts of French Stream through Rockland and the North River through Hanover. More problems are expected with the rapid development in this basin, if proper land use management is disregarded.

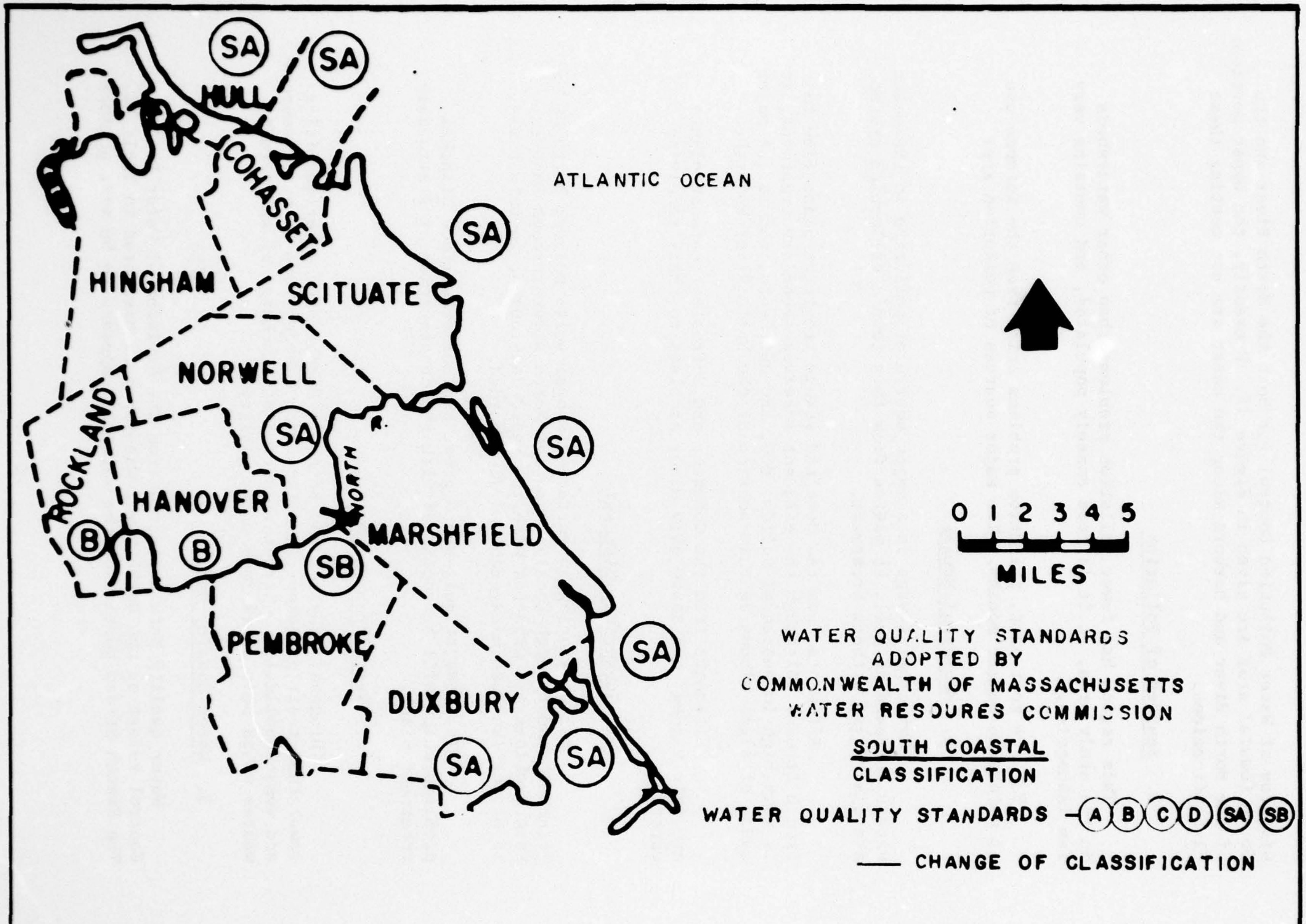
The town of Hull has a great deal of subsurface disposal problems which will be rectified with the construction of a secondary treatment plant.

c. Waste from Ships

Hingham, Cohasset and Scituate Harbor have water qualities lower than their proposed classifications, largely due to small sources and vessel pollution. Stricter control of discharge of watercraft wastes would help to improve water quality.

3. Water Quality Data

Water quality data collected from the Division of Water Pollution Control report on the North River Watershed is presented in Table 24. The French Stream portion of the watershed appears to be most polluted



ATLANTIC OCEAN
SA
SA
HULL
COHASSET
SA
HINGHAM
SCITUATE
NORWELL
ROCKLAND
SA
NORTH
R.
SA
HANOVER
MARSHFIELD
B
B
SB
PEMBROKE
SA
DUXBURY
SA
SA
0 1 2 3 4 5
MILES
WATER QUALITY STANDARDS
ADOPTED BY
COMMONWEALTH OF MASSACHUSETTS
WATER RESOURES COMMISSION
SOUTH COASTAL
CLASSIFICATION
WATER QUALITY STANDARDS — A B C D SA SB
— CHANGE OF CLASSIFICATION

Figure 12

TABLE 24

RANGE OF WATER QUALITY VALUES IN THE NORTH RIVER WATERSHED
(ppm unless otherwise designated) (32)*

	1. North River		2. Indian Head River		3. French Stream	
	Min.	Max.	Min.	Max.	Min.	Max.
DO	2.3	10.5	2.3	11.1	0	16.9
BOD_5	1.0	5.8	1.6	7.0	2.6	4.0
Suspended Solids	1.0	16.0	4.0	13.5	2.0	5.4
Alkalinity	7.0	11.0	1.2	20	25	90
Total Phosphorus	.04	.26	.40	.93	.19	5.30
Nitrate (NO_3-N)	0	.40	.30	1.0	0	1.50
Ammonia (NH_3-N)	.03	.60	.08	1.30	.04	10.00
Chlorides	77	14,000	32	75	22	78
Color (units)	0	800	100	375	90	200
Turbidity (T.U.)	0	45	2	3	2	16
Average Total Coliforms	$<$ 36	2,290	205	2,620	860	413,000
Average Fecal Coliforms	$<$ 36	920	36	810	50	232,000

Locations given in Figure 13

Water Quality Classifications
North River, Indian Head River, French Stream - Class B

*Samples taken 6/71 - 7/71

NORTH RIVER WATERSHED

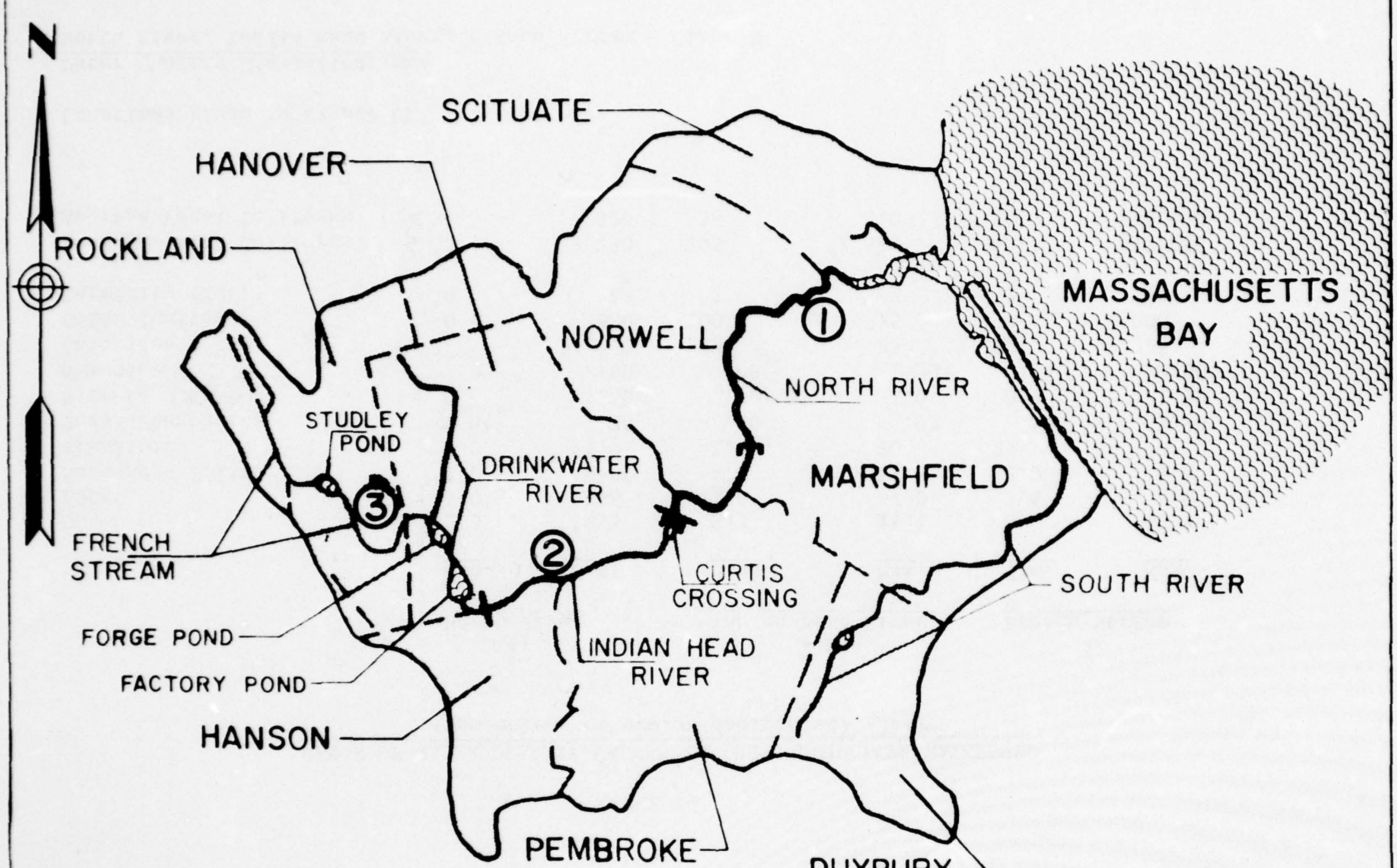


Figure 13

with nutrients and bacteria due to sewage treatment plant discharge and malfunctioning subsurface disposal systems. The Division of Water Pollution Control also measured metal concentrations in both water and sediments of the North River. Results of this study are given in Table 25 (32).

4. Effects of Pollution

a. Recreation

As pollution along the coast of this basin is limited to minor non-point sources, bathing beaches in the south coastal area are quite clean, and heavily utilized in the summer months by vacationers from areas surrounding Boston. Only in harbor areas, is swimming restricted due to poor water quality.

Swimming areas in upper portion of the North River Watershed have been closed due to high coliform counts and overabundance of algae.

b. Shellfish Harvesting Areas

Shellfish harvesting is restricted and prohibited along the coast of Hull due to raw sewage discharge, (See Figure 4). Shellfish harvesting is also prohibited in Cohasset Harbor and Scituate Harbor mainly due to the establishment of buffer zones for sewage treatment plant discharge, and vessel pollution. In Cohasset, a total of 80 acres is closed in Cohasset Harbor and the Gulf. In Scituate, 29 acres are closed in Scituate Harbor, and 13 more are closed in North Scituate. Shellfish harvesting areas in Marshfield along the Green Harbor River are also closed. Maps of closed areas are given in Figures 14 and 15 (15).

TABLE 25

RANGE OF TRACE METAL CONCENTRATIONS IN NORTH RIVER WATER AND SEDIMENT (ppm) (32) *

	Water	Sediment
Mercury	$<.00005$	.04 - 5.50
Cadmium	0 - .08	0 - 5.45
Lead	0 - .33	2.0 - 300
Zinc	0 - .34	9.0 - 98.5
Nickel	0 - .54	2.3 - 32.3
Copper	0 - .17	1.8 - 635.0
Chromium	0 - .08	4.0 - 363.0
Arsenic	-	0 - 4.4

*Samples taken 6/71 - 7/71

CLOSED SHELLFISH AREAS

COHASSET & SCITUATE

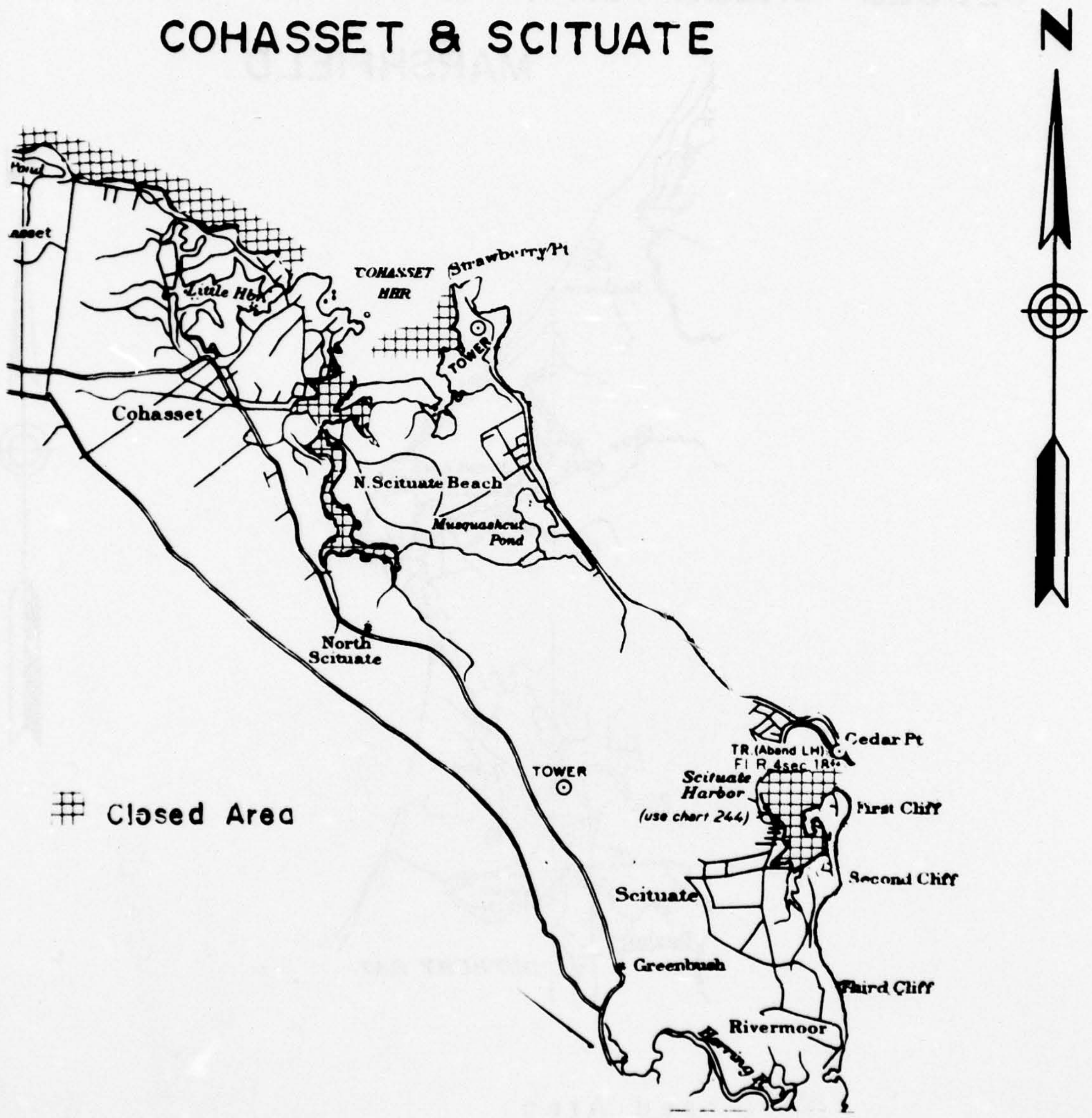
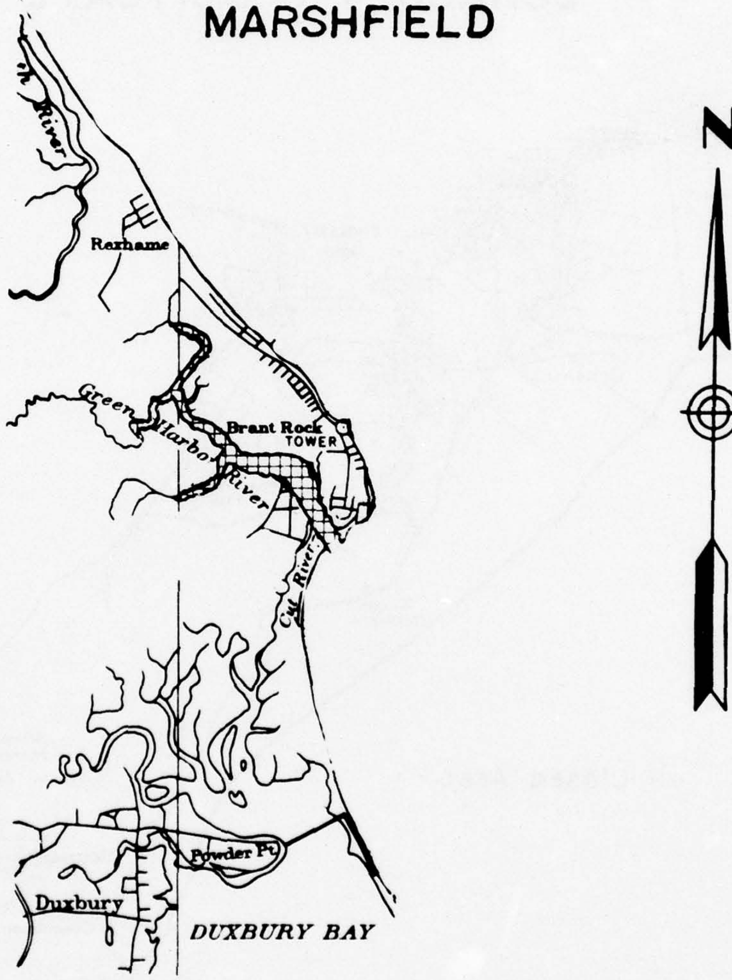


Figure 14

CLOSED SHELLFISH AREAS
MARSHFIELD



Closed Area

Figure 15

F. NORTH COASTAL - IPSWICH RIVER WATERSHED

1. Description of the Area

The North Coastal - Ipswich River Watershed includes the communities in the coastal region north of Boston, extending from Lynn to Ipswich, and the towns lying along the Ipswich River. The Ipswich River travels in a northeasterly direction from its source in Wilmington to its outlet to the ocean at Ipswich. The river is 35 miles in length, and has a drainage area of approximately 155 square miles (33). The towns in this region vary widely in character. Communities in the southern portion, such as Lynn, Peabody, and Salem have become quite industrialized and their population is near saturation. Towns to the north, especially along the Ipswich River, are still semi-rural in character, although they have experienced rapid growth in recent years. The BH - EMMA Study has projected that the population of many of the towns along the Ipswich River may almost double by the year 2000.

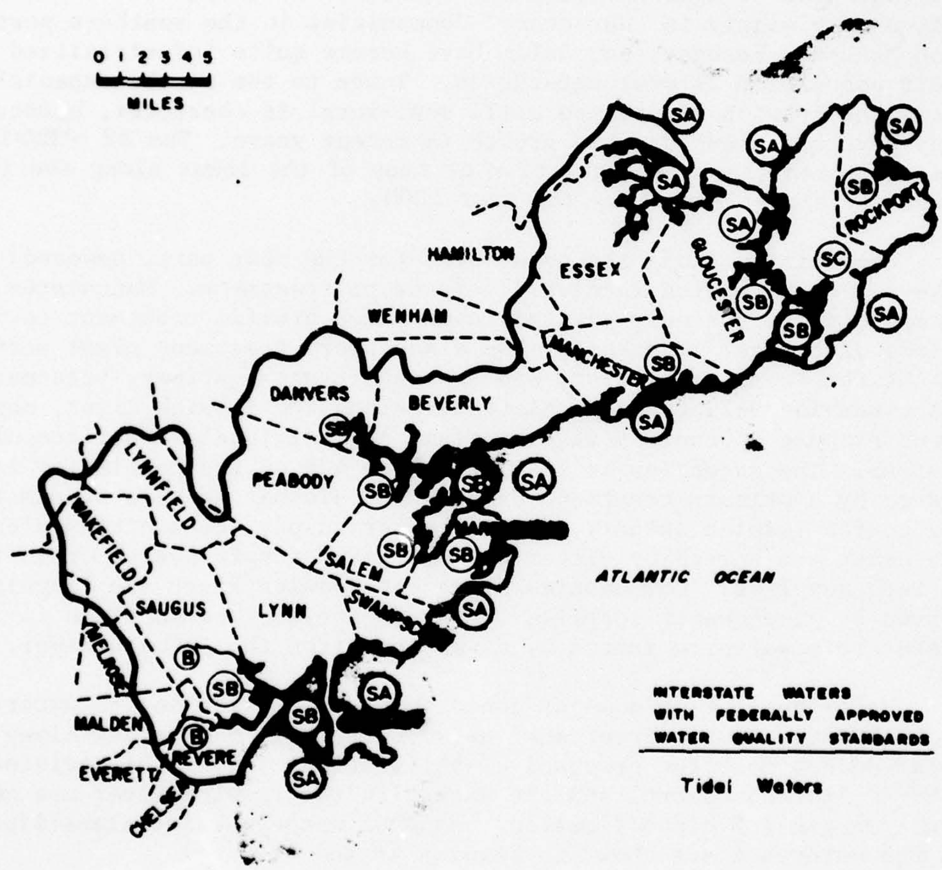
Communities along the coast are, for the most part, sewered; however, their wastes receive little or no treatment. Manchester and Swampscott are the only coastal towns which provide treatment to wastes before discharge. Manchester has a secondary treatment plant serving 70% of the towns population, and Swampscott has a primary treatment plant serving 94% of the population. Along the Ipswich River, most towns dispose of their sewage by means of individual subsurface disposal systems. The exception is Ipswich, where 40% of the population is served by a primary treatment plant which discharges to a stream flowing to the Ipswich estuary. As for water supply, communities along the coast are served by either the MDC water supply system or municipal surface supplies. Communities along the Ipswich River are largely served by groundwater supplies. Many of the surface supplies in this basin are reservoirs formed by diversions from the Ipswich River.

Water quality is a major concern in this region as its waters are in high demand for recreational use. Currently, many areas along the coast do not meet the proposed classifications set by the Division of Water Pollution Control and the waters in the Ipswich River are meeting a marginal B classification. Maps of water quality classifications in the watershed are shown in Figures 16 and 17.

2. Sources of Pollution

a. Municipal Sewage

Raw municipal sewage is the greatest pollution problem in the coastal waters of this region, as most coastal towns discharge untreated sewage to the ocean, endangering shellfish harvesting and bathing in many areas. These communities are listed in Table 26 along with information on population served and location of discharge.



WATER QUALITY STANDARDS
ADOPTED BY
COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION

NORTH COASTAL

CLASSIFICATION

WATER QUALITY STANDARDS - A B C D SA SB SC

— CHANGE OF CLASSIFICATION

Figure 16

AD-A036 811 METCALF AND EDDY INC BOSTON MASS F/G 13/2
WASTEWATER ENGINEERING AND MANAGEMENT PLAN FOR BOSTON HARBOR - --ETC(U)
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UNCLASSIFIED NL

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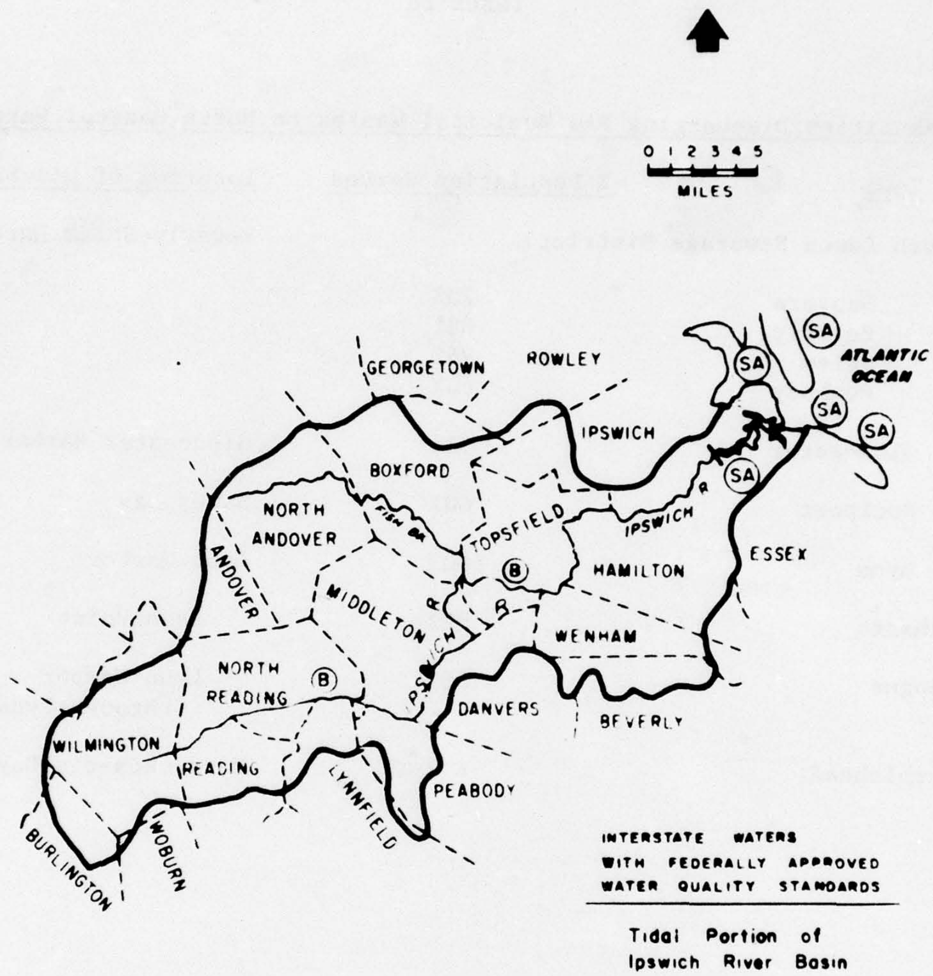


WATER QUALITY STANDARDS
ADOPTED BY
COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION

IPSWICH RIVER WATERSHED

CLASSIFICATION

WATER QUALITY STANDARDS - A B C D SA

— CHANGE OF CLASSIFICATION

Figure- 17

TABLE 26

Communities Discharging Raw Municipal Wastes to North Coastal Waters

Town	% Population Served	Location of Discharge
South Essex Sewerage District:		Beverly-Salem Harbor
Danvers	70%	
Beverly	88%	
Salem	96%	
Peabody	60%	
Gloucester	91%	Gloucester Harbor
Rockport	60%	Sandy Bay
Lynn	100%	Lynn Harbor
Nahant	92%	Bass Point
Saugus	56%	Lynn Harbor (through Lynn)
Marblehead	85%	Massachusetts Bay

b. Subsurface Disposal

The unsewered portions of towns along the coastline are experiencing subsurface disposal problems due to poor soils, and heavy loads put on these individual systems during the summer, when the population in these towns greatly increases. Portions of towns experiencing problems are the Lanesville section of Gloucester, the Magnolia section of Manchester, East Manchester, and the coastal areas of Rockport. The downtown section of Essex on the Essex River also has problems which have led to the closing of shellfish beds in this area.

The Ipswich River also receives wastes from malfunctioning subsurface disposal units. Major problems exist in West Peabody, Wilmington, Middleton, and two sections in North Reading; bacteria from these sources endangers swimming areas along the river. In many areas proper land use management would alleviate these problems.

c. Combined Sewers

Portions of Gloucester and Lynn are served by combined sewer systems which add significant amounts of pollutants to their respective harbors.

d. Solid Waste Disposal Sites

A landfill located on the tidal marshes between the Saugus and Pines River is causing severe problems in the Saugus and Pines River estuary. Leachate from this site has closed shellfish harvesting areas. The Ipswich River is also polluted with leachates from disposal sites along its shores. In Wilmington, a disposal site located in the watershed of Maple Meadow Brook, part of the headwaters of the Ipswich River, is causing low dissolved oxygen levels and high coliform counts. Disposal sites located in Middleton, on the Ipswich watershed, and Danvers, on a tributary to the Ipswich, also threaten the quality of the Ipswich River.

e. Urban Runoff

Towns along the southern portion of the north coastal region are quite urban in character, and significant volumes of runoff are carried to coastal waters and harbors during periods of rainfall.

3. Water Quality

Water quality data on the Ipswich River collected from reports published by the Division of Water Pollution Control is presented in Table 27 (33). No data on trace metals exists for this area, although metals concentrations here are thought to be quite low.

Very little data exists for the coastal water. Bacterial concentrations can be estimated from the status of shellfish harvesting areas (see pages 93, 94).

TABLE 27

RANGE OF WATER QUALITY VALUES IN THE IPSWICH RIVER
(ppm unless otherwise designated) (33)*

Ipswich River source to estuary	
DO	1-8.2
BOD_5	.6-3.0
Ammonia (NH_3-N)	0.0 - .28
Nitrates (NO_3-N)	0.0 - .5
Phosphorus	.05 - .17
Alkalinity	20-61
Suspended Solids	1-10
Total Coliforms (per 100 ml)	400-30,000
Turbidity (units)	2-4
Color (units)	65-116

Water Quality Classification
Ipswich River - Class B

*Sampling dates 6/73 and 8/73

4. Effects of Pollution

a. Shellfish Harvesting

Shellfish harvesting areas are closed in many portions of the north coastal region due to the large amounts of raw sewage that enter the water from both municipal and individual sources. Onshore watercraft wastes are another source of pollution in harbors.

All harvesting areas from the southernmost portion of Lynn through Beverly are closed, with the exception of a restricted area, 112 acres, on the Pines River in Saugus west of Route 107.

From Beverly Harbor to Ipswich, harvesting areas are open, with the exception of harbors, portions of the Annisquam River, which runs through Gloucester, and the tidal portions of the Essex and Ipswich Rivers. A total of over 2,300 acres of shellfish harvesting areas are closed in this region and over 300 acres are restricted (15). (See Figures 18 and 19, pages 93 and 94).

b. Bathing Areas

Bathing areas like shellfish areas are closed in harbors due to raw sewage outfalls. Despite the many sources of pollution along the coast, this area also has some very clean beaches, such as Cranes Beach in Ipswich. The Ipswich River is also used by local residents for both swimming and non-contact recreation such as boating and fishing.

c. Water Supply

Water supplies created by diversions from the Ipswich require minimum treatment of chlorination before use.

CLOSED SHELLFISH AREAS
NORTH COASTAL

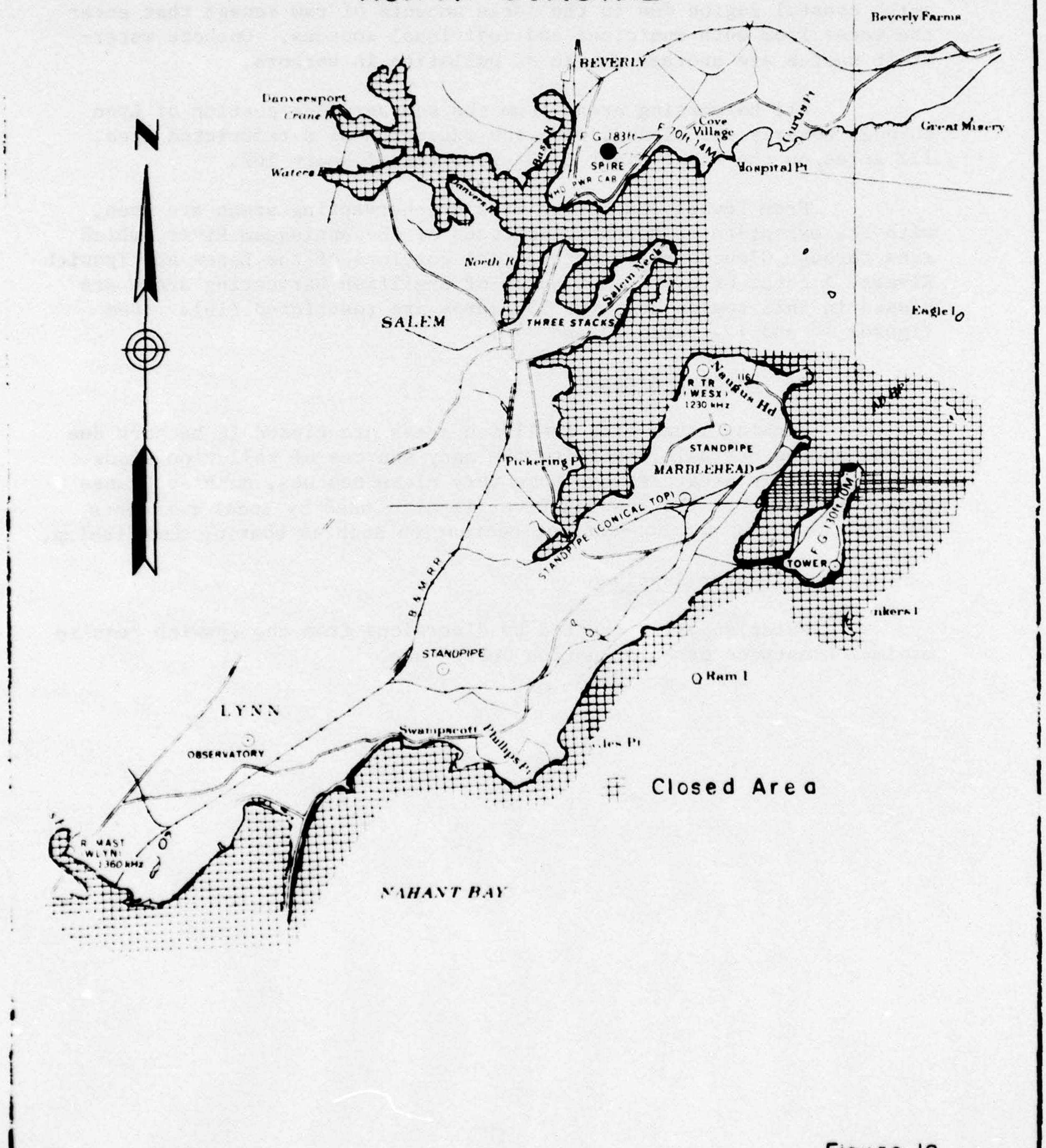


Figure 18

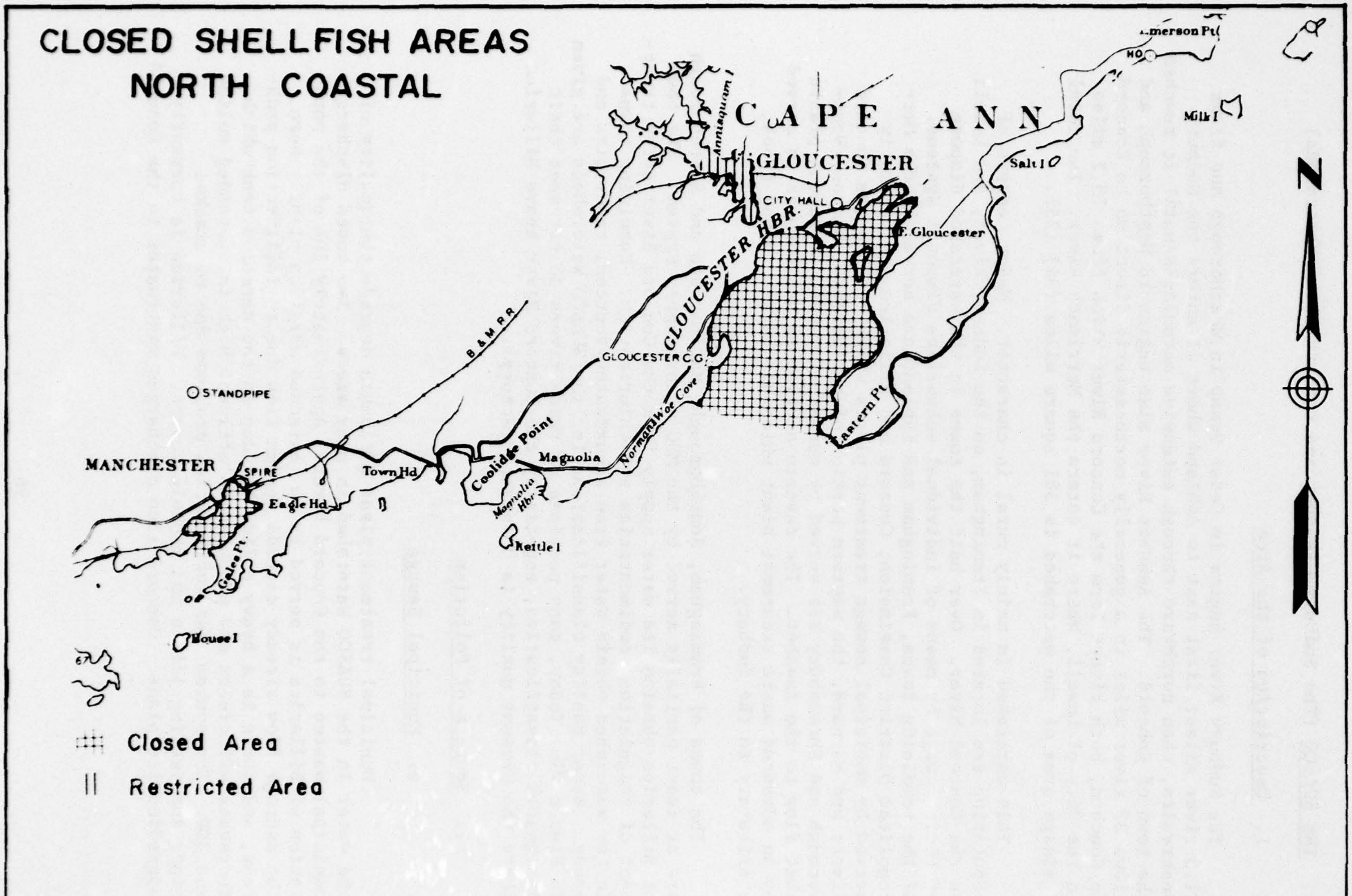

CLOSED SHELLFISH AREAS
NORTH COASTAL
CAPE ANN
GLOUCESTER
Annisquam R.
CITY HALL
GLOUCESTER HBR.
E. Gloucester
Eastern Pt.
Salt I.
Milk I.
Emerson Pt.
HO
N
B & M R R
GLOUCESTER C.G.
Norman's Woe Cove
Coolidge Point
Magnolia
Magnolia Hbr.
Kettle I.
Town Hd.
Eagle Hd.
SPIRE
MANCHESTER
STANDPIPE
Gales Pt.
House I.
Closed Area
Restricted Area

Figure .9

G. THE SUASCO (The Sudbury, Assabet and Concord River Watersheds)

1. Description of the Area

The Sudbury River begins in Cedar Swamp in Westborough and flows 31.3 river miles; first east to Ashland where it enters the Sudbury Reservoirs, then northward through extensive marshlands until it reaches the town of Concord. The Assabet River also begins in Westborough and flows 32 river miles in a generally northeasterly direction to Concord. In Concord, both rivers form the Concord River which flows 15.2 miles to the City of Lowell, where it enters the Merrimack River. The total drainage area of the watershed is 381 square miles (34) (35).

This watershed is mainly rural in character. Major centers of population are located in Framingham, on the Sudbury River, and Lowell on the Concord River. Over half the towns in the watershed dispose of their sewage by means of individual subsurface disposal systems. Of the remaining towns, Framingham and Ashland are served by the Metropolitan District Commission; Concord and Billerica are partially served by municipal sewage treatment plants which flow to the Concord River; and Maynard, the western portion of Marlborough, Hudson, Westborough and Shrewsbury are served by municipal sewage treatment plants that flow to the Assabet. The eastern section of Marlborough is served by an advanced waste treatment plant which discharges to Hop Brook, a tributary to the Sudbury.

The towns of Framingham, Southborough, Marlborough and Northborough are at least partially served by the MDC water supply system. The town of Billerica obtains its water supply from the Concord River after treatment of coagulation, sedimentation and chlorination. Remaining towns in the watershed obtain water from groundwater sources, reservoirs and ponds. Water quality classifications for the SUASCO Watersheds are given in Figure 20. Today, many portions of these rivers do not meet their designated classification, especially the Concord River above Billerica where the present quality is U (unsatisfactory).

2. Sources of Pollution

a. Municipal Sewage

Municipal treatment plant effluents degrade the quality of the water in the SUASCO Watershed in many areas. Two towns discharge municipal wastes to the Concord River. Approximately 10% of the population of Billerica is served by an extended aeration plant. Here, the average flow already exceeds design flow due to infiltration problems, and there is a heavy solids buildup in the aeration tank which decreases efficiency and produces an effluent high in suspended solids and BOD. The system has infiltration problems due to cracked pipes and leaking joints and manhole covers. Billerica is currently upgrading its plant. Concord also discharges wastewater to the Concord

WATER QUALITY STANDARDS
ADOPTED BY
COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION

CONCORD, ASSABET, & SUDBURY RIVER WATERSHED
CLASSIFICATION

WATER QUALITY STANDARDS - A B C D
— CHANGE OF CLASSIFICATION

Figure 20

River. Forty percent of the town is served by a treatment plant that employs primary treatment, filtration and chlorination. Effluents from this plant are found to be of fairly high quality, although the average flow is reaching design flow due to infiltration.

A new advanced waste treatment plant has just been constructed to serve the eastern portion of Marlborough. Effluents from this plant are discharged to Hagar Pond which flows to Hop Brook, a tributary to the Sudbury River. This plant replaces the former secondary plant whose effluents were causing algal blooms in Hagar Pond.

The remaining treatment plants in the watershed discharge effluents to the Assabet River. Ninety percent of Hudson, and 60% of Marlborough are served by secondary treatment plants discharging fairly good quality effluents; although both plants occasionally experience reduced efficiency caused by industrial wastes in their influents.

Approximately 30% of Westborough and 90% of Maynard are served by malfunctioning secondary treatment plants, which discharge effluents high in bacteria, organic matter and nutrients to the Assabet.

The Westborough plant is subject to frequent hydraulic overload due to infiltration of old sewer lines. Also leachate from the plant's sludge drying beds is polluting a nearby brook. The results of the sampling program for the Merrimack Wastewater Management Study (36) show fecal coliform bacteria counts as high as 500,000/100 ml. and concentrations of nitrates as high as 45 mg/l and phosphorous as high as 22 mg/l in the effluent.

The Maynard wastewater treatment plant also suffers reduced efficiency due to infiltration and toxic industrial wastes in the influent. Overloaded sludge digesters and overfilled sludge drying beds are causing further water quality problems. Maynard is currently converting its trickling filter plant to activated sludge.

The town of Shrewsbury, which is outside the study area, also has a secondary treatment plant that discharges poor quality effluent to the Assabet River. Results of the sampling program for the Merrimack Wastewater Management Study (36) show coliform bacteria counts as high as 150,000/100 ml as well as high nutrient concentrations in the effluent. This plant is subject to hydraulic overload from excessive infiltration. Sludge from this plant was formerly dumped in a nearby swamp until two towns, whose areas included part of the wetlands, threatened court action. Sludge is now being transported to a sanitary landfill.

Most wastewater treatment plants along the Assabet practice seasonal chlorination. This practice of disinfection from April through October is a public health hazard as some bacteria and many viruses may still survive long periods of time in winter.

b. Individual Subsurface Disposal Systems

Over one half of the communities in the SUASCO Watershed dispose of their wastewater totally by individual subsurface disposal systems. (See Table 28).

Because these systems may be one of the major water pollution sources in the watershed, a brief explanation of individual systems and the laws governing their installation will be presented here.

The most common type of subsurface disposal system is the septic tank with leaching bed. The septic tank is basically a settling tank which allows suspended solids to settle out, and reduces BOD by 15-30%. After a detention time of 24 hours the wastewater is distributed to a leaching bed where it percolates to the soil. A major portion of pollutants are removed by the soil system (see section on Land Application). The soils ability to absorb effluent is measured by the percolation test. Failure of the soils absorption ability results in backup of wastewater into the plumbing system or overflow onto the ground. Such a failure may occur because of inadequate percolation tests, insufficient leaching area for the volume of wastewater, or insufficient distance between the leaching area and the top of the groundwater table.

The Massachusetts Department of Public Health has set up standards and guidelines for disposal of sewage in unsewered areas through Article XI of the State Sanitary Code (37). The Code sets an upper limit on a soil percolation rate for individual systems at 30 minutes per inch and specifies a distance of 4 feet between the bottom of the disposal bed and the top of the groundwater table. The Code also specifies a minimum distance of 100 feet from leaching fields to surface water supplies or tributaries to water supplies. For other water courses a mimimum distance of 75 feet for single dwellings and 100 feet for multiple dwellings is recommended. In addition, the Code recommends, but does not require, that additional adequate area for disposal be reserved for reconstruction of the system.

Chapter 111, section 17 of the General Laws of Massachusetts requires that the Massachusetts Department of Public Health approve all plans for individual sewage disposal systems which treat over 2000 gallons per day. All systems must be approved by the local Board of Health and are subject to the regulations of Article XI of the State Sanitary Code.

Although these laws and regulations do exist, there are many subsurface disposal pollution problems in the SUASCO Watershed. The rapidly developing town of Acton is currently unsewered, yet its soils are particularly poor for adequate subsurface disposal treatment. Problems exist in the center of town and along route 2A, where many apartment complexes and condominiums are located. Health officials report that 75% of the systems in Acton fail within 2 to 4 years after installation (36).

TABLE 28

POPULATION UNSEWERED IN THE SUASCO WATERSHED

Town	Population (1970)	% Unsewered	Population Unsewered
Acton	14800	100%	14800
Ashland	8900	80%	7730
Berlin	2200	100%	2200
Billerica	31600	90%	28440
Bolton	1800	100%	1800
Boxborough	1500	100%	1500
Carlisle	2900	100%	2900
Chelmsford	31400	100%	31400
Concord	16100	60%	9660
Framingham	64000	10%	6400
Hudson	16100	10%	1610
Marlborough	27900	40%	11160
Maynard	9700	10%	970
Northborough	9200	100%	9200
Southborough	5800	100%	5800
Sudbury	13500	100%	13500
Wayland	13500	100%	13500
Westborough	12600	70%	8820
Total	283,500	Total	171,390

% Population Unsewered = 60%

The Merrimack Wastewater Management Study (36) found that water samples taken from a Nagog Brook tributary and Nashoba Brook (both tributaries to Nagog Pond, the Concord water supply) to be high in fecal coliform bacteria counts and color. The Nagog Brook tributary also had iron and manganese concentrations above current U.S. Drinking Water Standards concentrations.

The towns of Bolton and Berlin and the section of Boxborough along Beaver Brook are also experiencing subsurface disposal problems. The sampling program found fecal coliform counts as high as 9,900 in Bolton Center Brook.

On-lot disposal problems in all these towns are attributed to poor soils, faulty system design, inadequate disposal area for the volume of waste treated, and inadequate distance between disposal beds and surface or groundwater.

The State Sanitary Code has no land use regulations. Towns may set up zoning laws to prohibit or limit development in certain areas. However these laws do not consider soil types, or the soils ability to handle wastewater generated. Oftentimes disposal systems are constructed in the least desired area of the lot.

In addition, Massachusetts has no regulations dealing with septic tank pumping. Pumping is the owners responsibility, and it is common practice that the tank is pumped only when failure occurs. Failure to pump accumulated solids at least once every 2-3 years will cause a reduction in the systems BOD removal. An increased load of BOD and suspended solids entering the soil will decrease the soils ability to treat the effluent.

Disposal of septic tank pumpings is another problem. This sludge is often transported to local dumps or sanitary landfills where it causes odor problems as well as pollution of nearby streams and groundwater through runoff and percolation. Large quantities of septic tank sludge cannot be pumped into municipal wastewater treatment plants. If treatment plants are adequate, the sludge may be bled in slowly.

As water resources in the SUASCO watershed continue to be polluted by faulty on-lot disposal systems, it appears that there is a need for stricter laws and regulations concerning these systems and stronger enforcement of these laws by both the State and local Boards of Health.

c. Solid Waste Disposal Sites

In the SUASCO Watershed, many solid waste disposal sites are located on lands such as swamps and in the groundwater table, which are generally unsuited for any other use. Wetland areas are particularly poor solid waste disposal sites as wetland water usually has a very low pH, which results in ionization of metals.

The Merrimack Wastewater Management Study sampling program (36) tested several streams flowing near solid waste disposal sites (see Table 29). Concentrations of the metals iron and manganese were quite high in some of these streams. Second Division Brook near the Maynard Dump had iron concentrations as high as 4.1 mg/l and manganese concentrations as high as 1.1 mg/l. This dump is located on an old gravel excavation site in the groundwater table.

Crystal Brook at the Hudson dump had the highest iron and manganese concentrations: 58 mg/l and 20.5 mg/l respectively.

High annual rainfall in Massachusetts contributes to the landfill leachate problems, and makes proper disposal sites, leachate control, and adequate soil cover a necessity.

3. Water Quality Data

Data collected from the Division of Water Pollution Controls report on the Concord and Sudbury Rivers, 1973, and report on the Assabet River 1968 are presented in Table 29 (34) (35). Values for coliform bacteria are high in all streams, especially the Assabet River. High nutrient concentrations and BOD in Hop Brook and the Assabet may be attributed to malfunctioning sewage treatment plants and individual subsurface disposal systems. Data on Hop Brook was taken in 1973. Since this time the Marlborough East wastewater treatment plant, which discharges to this brook has been upgraded and converted to advanced waste treatment. Today nutrient concentrations and BOD in this stream should be much lower.

Very little flow data exists for rivers in the SUASCO watershed. The U.S. Army Corps of Engineers report a 7 day 10 year low flow of 1.2 cfs on the Sudbury at Framingham, 2.4 cfs on the Assabet at Hudson and 22 cfs on the Concord River at Concord.

Low flow in the Sudbury is augmented, especially in summer months, by water from the Sudbury Reservoirs. These reservoirs supply the river with approximately 30 to 80 MGD.

Slow moving areas in both the Sudbury and Assabet Rivers contain algal blooms due to high nutrient loads.

4. Effects of Pollution

a. Recreation Areas

High coliform values in the Concord, Sudbury and Assabet Rivers prohibit swimming. High nutrient levels in these streams promote algal growth and stagnant unpleasant conditions in many slow moving areas. Low dissolved oxygen concentrations make many portions of these rivers uninhabitable for fish and other aquatic life. Lakes and ponds tributary to these rivers are used for swimming and fishing, however

TABLE 29

RANGE OF IRON AND MANGANESE CONCENTRATIONS (mg/l)
IN STREAMS FLOWING BY SOLID WASTE
DISPOSAL SITES IN THE SUASCO WATERSHED (36)*

Site	Stream	Fe (mg/l)	Mn (mg/l)
Billerica	Canal East	.36-.62	.12-.34
Billerica	Canal West	.43-.75	.13-.46
Hudson	Crystal Spring Br.	58	20.3
Harvard	Elizabeth Brook	.34-.57	.09-.32
Maynard	Second Division Brook	1.5-4.1	.35-1.1

*Samples taken 8/73 - 5/74

TABLE 30

RANGE OF WATER QUALITY VALUES IN THE SUASCO WATERSHED (34) (35)*
(ppm unless otherwise designated)

	1. Sudbury River		2. Concord River		3. Hop Brook		4. Assabet River	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Dissolved Oxygen	1	12.9	1.1	12.2	1.9	24.3	.4	11.9
BOD_5	1	7.5	1.5	8.2	2.0	87.0	1.0	14
Ammonia (NH_3-N)	0	.43	0	.59	.05	28	.07	5.3
Nitrates (NO_3-N)	0	.5	.1	.5	.1	1.3	0	2.0
Total Phosphorus	.02	.40	.18	.35	.44	3.9	.07	3.7
Alkalinity	10	30	23	26	16	78	10	55
Suspended Solids	1.0	22.0	1.0	23.0	1	50.0	1.0	56.0
Coliforms	700	900,000	700	150,000	200	900,000	36	1.5×10^6
Fecal Coliforms (per 100 ml)							36	460,000
Color (units)							10	100
Turbidity (units)							1	18

Locations are given in Figure 21

Water Quality Classifications

Sudbury Reservoir and tributaries, Nagog Pond and tributaries	-	Class A
Sudbury River, Assabet River and Concord River from source to Talbot Dam, No. Billerica	-	Class B
Concord River, Talbot Dam to Merrimack River	-	Class C

*Sampling dates for Sudbury and Concord Rivers and Hop Brook 7/73 - 8/73
Sampling dates for Assabet River 7/67 and 8/67


CONCORD SUDBURY & ASSABET
RIVER WATERSHED
MERRIMACK
RIVER
Lowell
Tewksbury
Chelmsford
RIVER
Billerica
2
Carlisle
CONCORD
Bedford
Boxborough
Concord
Stow
Lincoln
RIVER
4
Berlin
WATERSHED LOCATION
Sudbury
RIVER
Hudson
ASSABET
HOP
BROOK
3
Wayland
Weston
Marlborough
SUDBURY
Framingham
LAKE
COCHITUATE
Northborough
SUDBURY
RESERVOIR
Natick
Southborough
1
Westborough
SUDBURY
RIVER
Ashland
Sherborn
North
Hopkinton
Upton
Holliston
0 1 2 3 4 5
MILES

Figure 21

their quality is often endangered by polluted feeder streams.

b. **Water Supplies**

Only the town of Billerica obtains its water supply from one of the rivers in the SUASCO Watershed, and this water must receive a high degree of treatment before use. Many lakes and ponds in the watershed, such as Nagog Pond in Acton, are used as a source of water supply. The quality of these surface supplies is often threatened by feeder streams polluted by malfunctioning subsurface disposal systems and other non-point sources. Groundwater supplies in the watershed are also endangered by inadequate individual disposal systems and improperly located and maintained solid waste disposal sites.

H. AREAS AFFECTED OUTSIDE STUDY AREA

Areas outside the study area affected by Concept 5 (land application) are located in the Lower Taunton River Watershed and within the South Coastal-Buzzards Bay and Cape Cod Watersheds.

1. The Taunton River Watershed

The Taunton River and its complex of tributaries, drains 530 square miles of southeastern Massachusetts and empties into Mount Hope Bay, a sub-basin of Narragansett Bay. The major population centers in the watershed are the industrial cities of Brockton, Taunton and Fall River. The remainder of the watershed is largely rural with a significant portion of the land devoted to farming, cranberry cultivation, and sand and gravel excavation.

Water pollution problems in the Taunton Watershed stem from inadequately treated major municipal and industrial discharges, combined sewer overflows, and stormwater runoff in urban areas, and from agricultural runoff, inadequate disposal of cattle wastes, malfunctioning subsurface disposal systems, sand and gravel operations and poorly operated solid waste disposal sites in rural areas (38).

Sites proposed for land application lie within the Mount Hope Bay sub-basin, largely in the towns of Fall River, Freetown, Lakeville and Berkley, with portions in Dartmouth and Westport. A total of 7,130 acres of land in these towns were found to be suitable and available for land application of wastewater effluents (39).

The towns of Freetown, Lakeville, Berkley and Westport are sparsely populated; they have no municipal water supplies and no municipal sewerage systems. The town of Dartmouth is supplied with water by New Bedford which obtains its water from three ponds in Lakeville. This town is also served by a secondary waste treatment plant discharging to Buzzards Bay. Fall River, a city with a population of 105,000 obtains its water supply from North Watuppa Pond and Copicut Reservoir in Fall River. The city is served by a primary waste treatment plant discharging to Narragansett Bay.

In Freetown, the proposed site located closest to developed land, is in the Freetown-Fall River State Forest. Another site proposed north of the State Forest is in an area where gradual development is taking place and in close proximity to a large cranberry bog and the Freetown Dump. Other proposed sites in Freetown are on undeveloped land.

In Lakeville, all proposed sites are located in the southwest corner of town near the Lakeville-Freetown boundary. The town of Lakeville contains three large ponds which supply water to the city of New Bedford and Dartmouth; however, proposed spray irrigation sites are located a good distance from these ponds. The site extending over the Freetown-Lakeville boundary does lie near the previously mentioned cranberry bog in Freetown.

All proposed application sites in Berkley are on undeveloped land.

In Fall River, 1523 acres of the proposed sites lie within the Freetown-Fall River State Forest and the Watuppa Reservation, both recreation areas (39). The remainder of sites lie south of the State Forest and southeast of Watuppa Reservation. This area is quite undeveloped with no access roads. Some sites in this area lie close to Copicut Reservoir, part of the Fall River Water Supply.

In Dartmouth, a large portion of the land proposed for land application is part of the Fall River site which lies near Copicut Reservoir.

The few proposed sites in Westport are in an undeveloped area in the northeast sector of the town.

2. South Coastal-Buzzards Bay Area

In the South Coastal area, land application sites totalling 8086 acres are proposed in Plymouth, Carver and Wareham (39).

Plymouth has the largest area of any town in Massachusetts. Its good soil and topography make practically all the town's land capable of development. Presently, only the area in the northeast section between Route 3 and the coast is highly developed. Other developments are located along existing roads. The town's long shoreline and large number of lakes and ponds make it an important recreational area in the summer months. In fact, 9600 acres of the town is occupied by Myles Standish State Forest which is heavily used for camping, picnicing swimming and bicycling. Plymouth obtains a major portion of its water supply from three ponds located north of the State Forest. The town is also served by a secondary wastewater treatment plant which discharges to Plymouth Bay. Water pollution problems in the town exist primarily along the coast due to industrial and sanitary discharges and waste from ships.

Half of the acreage proposed for land application lies with the Myles Standish State Forest. Buffer zones of 1000' have been proposed around ponds and campsites and 200' along roads. The remainder of proposed sites lie in undeveloped areas in the southern portion of the town. Some sites are located near large cranberry bogs.

Carver contains many acres of undeveloped land. The town is sparsely populated, and has no municipal water supply nor sewerage system. Only minor water quality problems exist due to runoff from numerous cranberry bogs dispersed throughout the town. Most of the proposed land application site in Carver lies in the Myles Standish State Forest in the eastern portion of town. This area is located near a large cranberry bog.

The town of Wareham lies along Buzzards Bay. Major development

lies along the coast; its northern portion is largely undeveloped and abounds in cranberry bogs. The town obtains its water supply from wells in the northern section of town and its domestic wastes are handled by individual subsurface disposal units. Pollution problems exist on the coast and along the Wareham River due to stormwater runoff and vessel wastes, and along the Agawam River due to faulty septic tanks. Runoff containing pesticides and fertilizer from numerous cranberry bogs may also be causing problems in ponds and streams running through the town. The proposed land application sites in Wareham are in the northeast section of town, where many cranberry bogs are located.

3. Cape Cod

A total of 3475 acres of land in Bourne and Sandwich are proposed for land application sites (39).

The town of Bourne contains many acres of undeveloped land. Its major centers of development lie along the coastal areas of Buzzards Bay and Cape Cod Bay. A large portion of the land, south of the Cape Cod Canal, is occupied by Otis Air Force Base.

Bourne has four water districts; Buzzards Bay, Bourne, North Sagamore and South Sagamore. Each district has separate wells which supply different sections of the town. The town has no municipal sewerage system, and is currently experiencing subsurface disposal problems in densely populated areas of Buzzards Bay, Monument Beach, Pocasset and South Sagamore. Pollution from faulty subsurface disposal units and watercraft discharges are the only sources of pollution to the town's relatively clean coastal waters.

In Bourne, 498 acres on Otis Air Force Base are proposed for rapid infiltration, and 729 privately owned acres, north of the Cape Cod Canal and west of Route 3, are proposed for both spray irrigation and rapid infiltration. All sites are on undeveloped and sparsely developed land. The sites north of Cape Cod Canal lie near a few cranberry bogs, and a small rapid infiltration site on the northwestern side of the canal lies near water supply wells.

The town of Sandwich also contains many acres of undeveloped land. Development exists mainly around the Sandwich Center and Town Neck. Again, a large portion of the town is occupied by Otis Air Force Base. The town obtains its water supply from three wells in the eastern portion of town. The town has no municipal sewage system, and is currently experiencing subsurface disposal problems in highly developed areas as house lots in these areas are too small to adequately handle wastes. Otis Air Force Base does have a small wastewater treatment plant which employs trickling filters, sand filters and ground disposal. This plant is presently quite underused. Over two thousand acres of undeveloped land in Sandwich on Otis Air Force Base are proposed for rapid infiltration (39).

III. ASSESSMENT OF HYGIENIC IMPACTS

A. METHODOLOGY FOR IMPACT ASSESSMENT

Impact assessment is the analysis and evaluation of change that can be expected if a proposed alternative for wastewater management is implemented. This hygienic impact assessment addresses changes in water quality and water use brought about by the implementation of proposed wastewater management alternatives for the Boston Harbor- Eastern Massachusetts Metropolitan Area (BH-EMMA). Changes will be measured against a base line condition which is a continuance of existing arrangements for wastewater management in the study area (the no action alternative). A state-EPA implementation plan does not exist for the entire study area. Towns currently under implementation schedules for wastewater treatment will be mentioned. Four water-oriented and one land-oriented alternative concepts were originally proposed. The technical subcommittee for the BH-EMMA study, after considering impacts of these 5 alternative concepts, as well as public opinion, proposed a recommended concept (concept 6), which is a hybrid of the original five concepts. These 6 alternative concepts are shown in Figures 22-27.

The approach taken for this assessment is described below:

1. The effects of "no action" in the study area are discussed.

2. The impacts of concepts 1-5 are assessed separately for each watershed in the study area.

3. Concepts are broken down into plan elements for each area. Plan elements are actions proposed by a concept that will cause a change from base line conditions. Due to the level of detail of this study, only three types of plan elements are addressed.

a. Addition of advanced or secondary waste treatment facility effluent to an area that currently receives no such discharges.

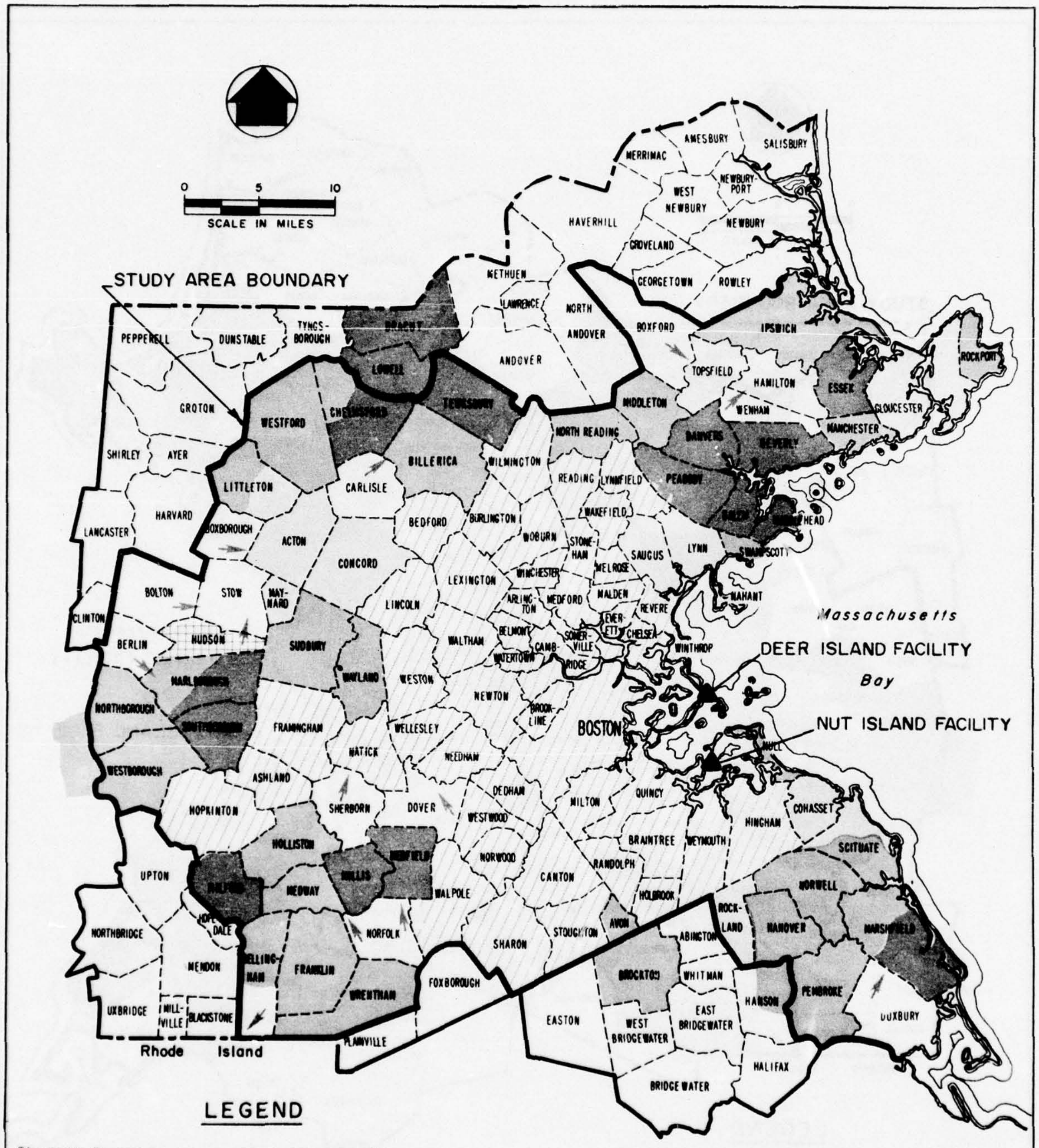
b. Change in level of wastewater treatment at a certain location.

c. Expansion or reduction of wastewater collection systems.

Both short and long term changes in environmental quality brought about by these plan elements are related to:

a. Characteristics of the effluent (both quality and quantity compared to the receiving body of water).

Effluent characteristics of hygienic concern are; pathogenic organisms (both bacteria and viruses), nitrates, and metals. An attempt is made to estimate the concentrations of pathogenic organisms and nitrates in receiving waters brought about by treatment facility discharges proposed in each concept. Concentrations of metals are not estimated as industries are required, under the Federal Water Pollution

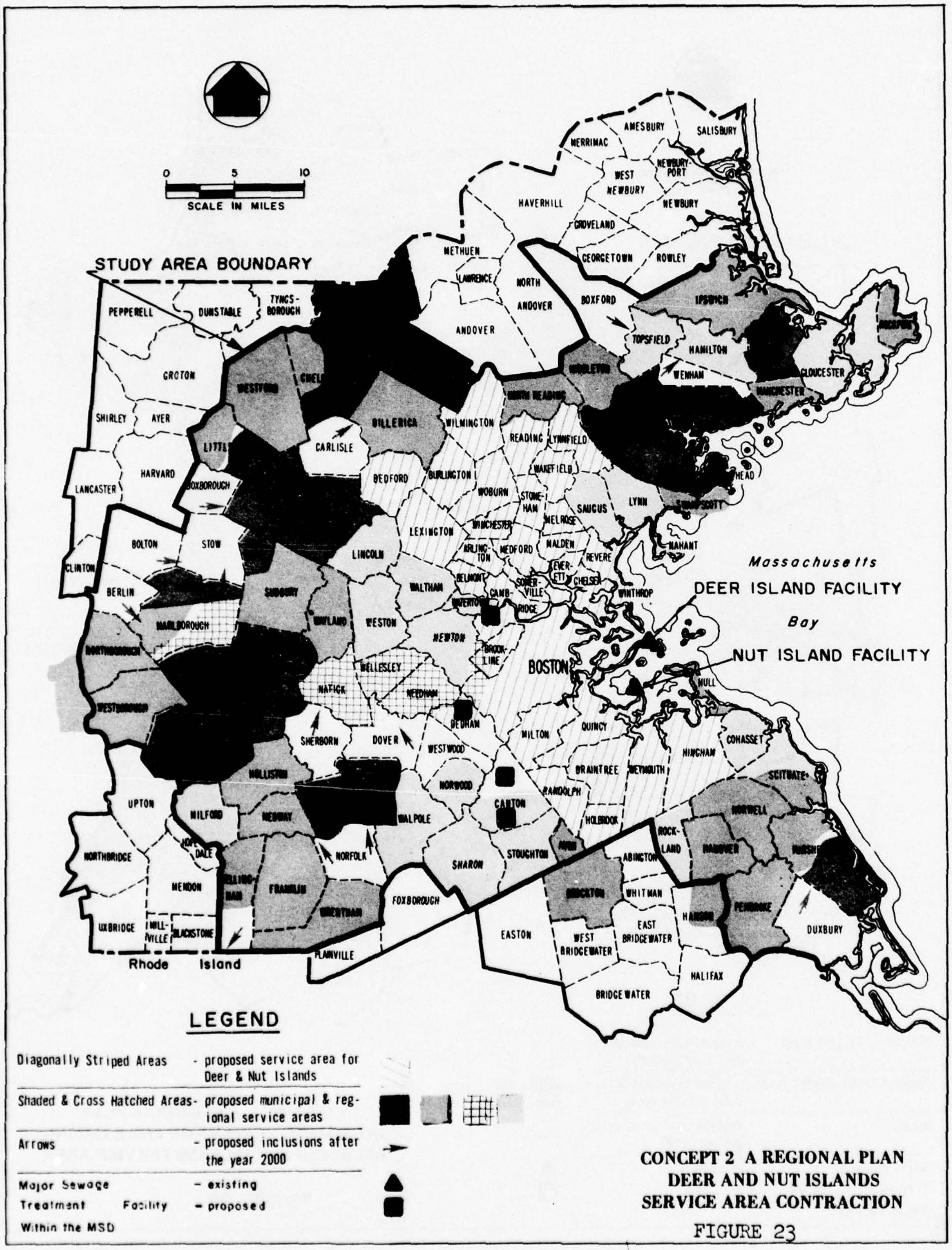


LEGEND

Diagonally Striped Areas	- proposed service area for Deer & Nut Islands	
Shaded & Cross Hatched Areas	- proposed municipal & regional service areas	
Arrows	- proposed inclusions after the year 2000	
Major Sewage Treatment Facility Within the MSD	- existing - proposed	

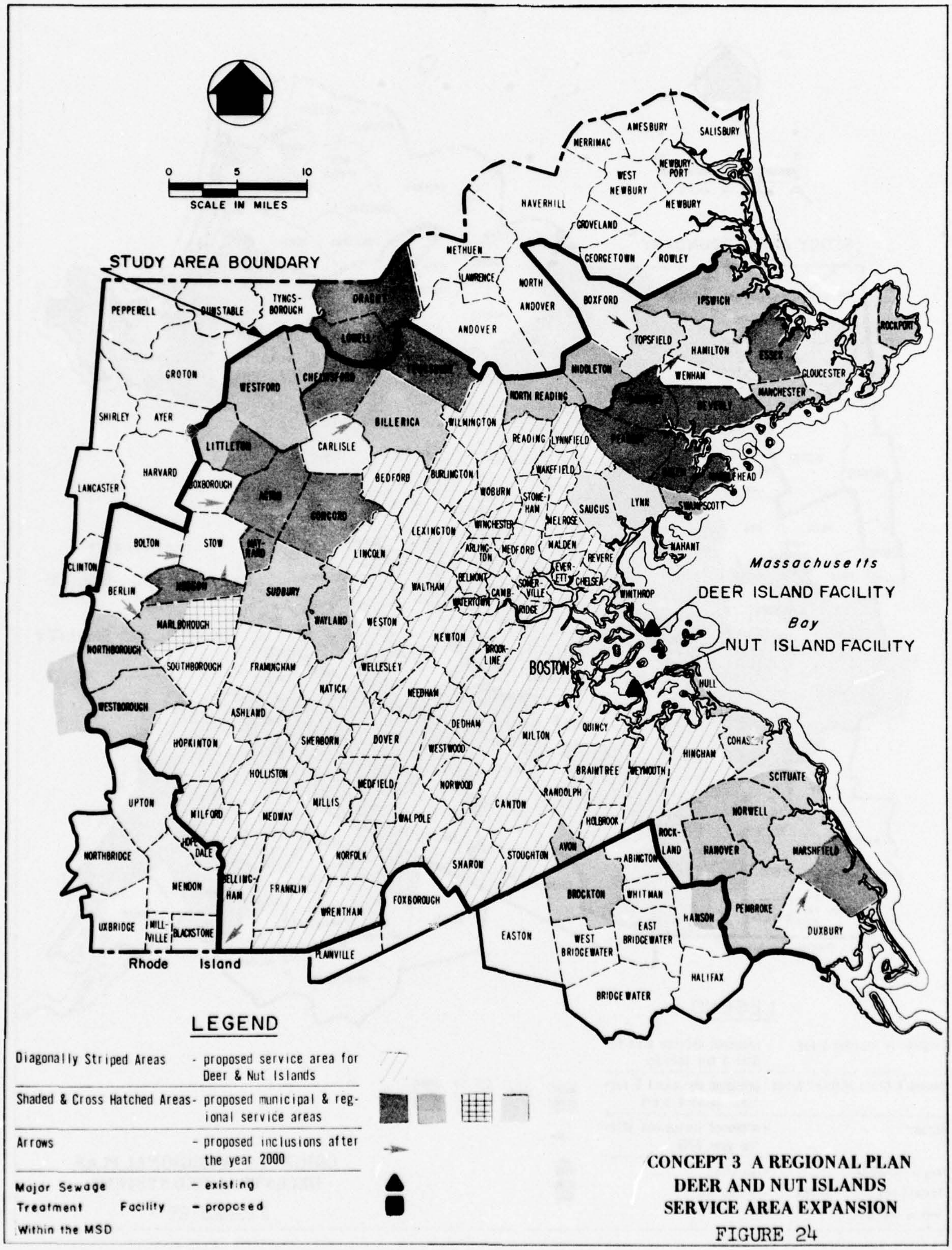
CONCEPT 1 A REGIONAL PLAN UPGRADING SYSTEMS OF THE EXISTING DEER AND NUT ISLANDS SERVICE AREA

FIGURE 22

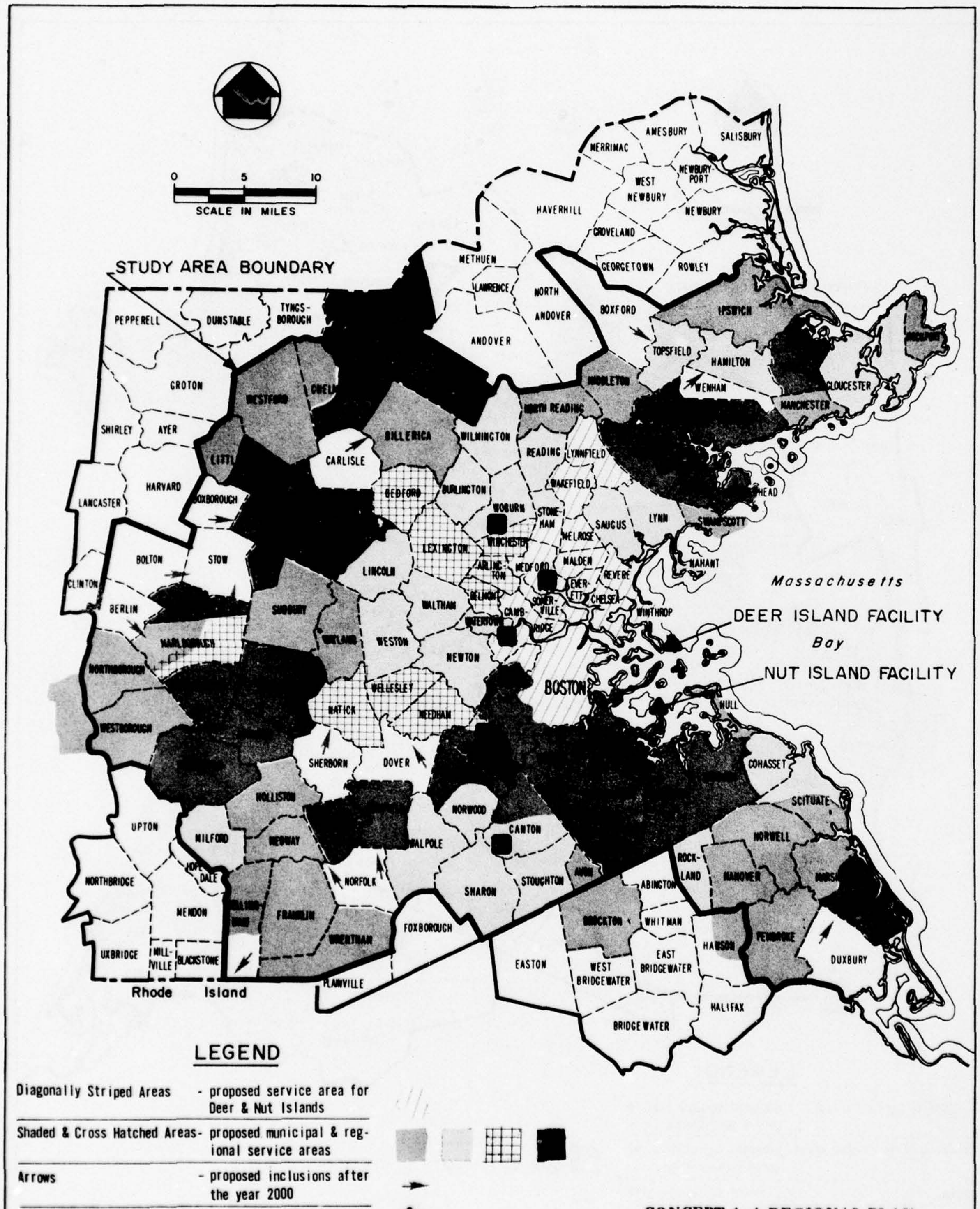


CONCEPT 2 A REGIONAL PLAN
DEER AND NUT ISLANDS
SERVICE AREA CONTRACTION

FIGURE 23



CONCEPT 3 A REGIONAL PLAN
DEER AND NUT ISLANDS
SERVICE AREA EXPANSION
FIGURE 24



CONCEPT 4 A REGIONAL PLAN DECENTRALIZED SYSTEMS

FIGURE 25

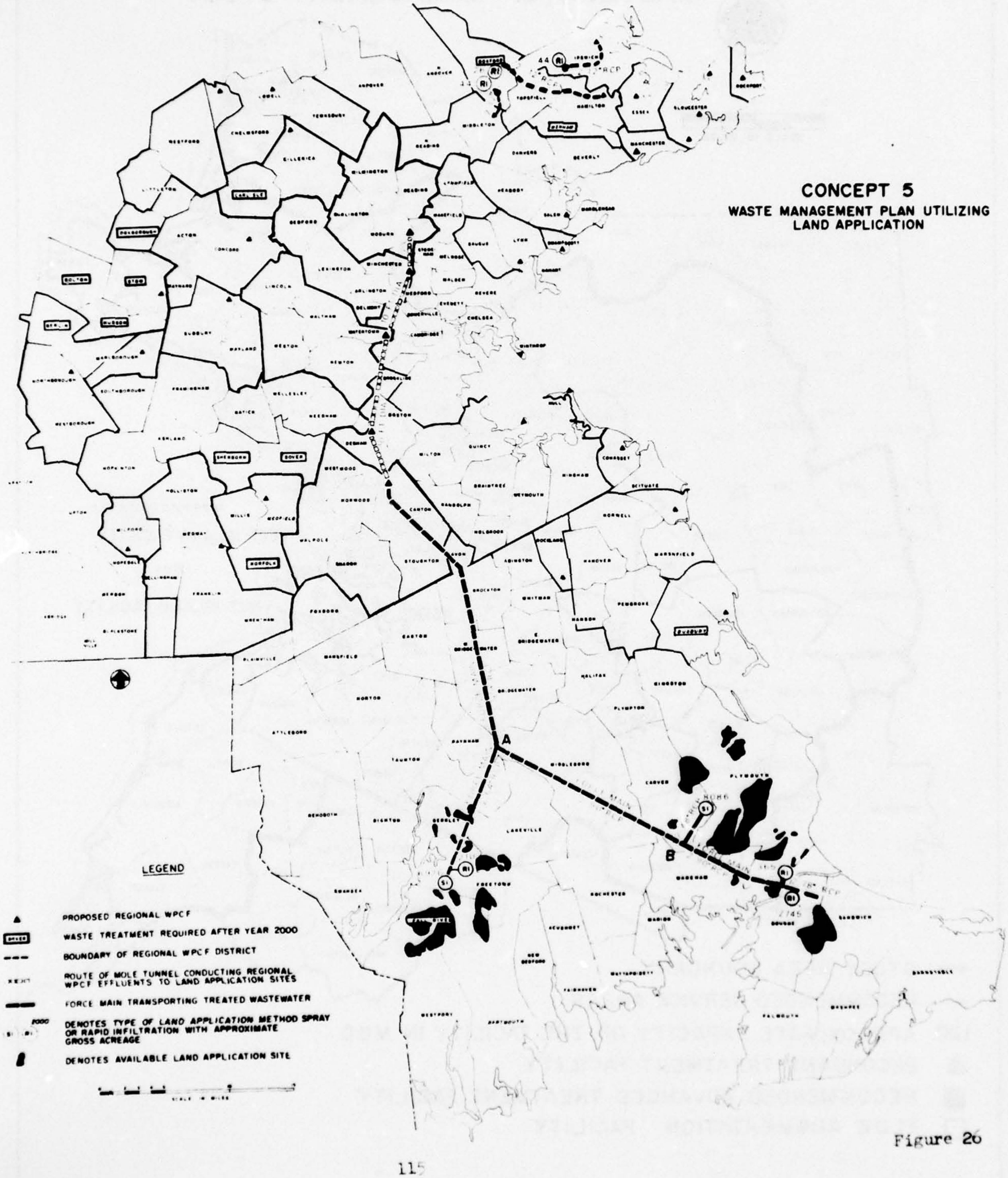

CONCEPT 5
WASTE MANAGEMENT PLAN UTILIZING LAND APPLICATION
LEGEND
PROPOSED REGIONAL WPCF
WASTE TREATMENT REQUIRED AFTER YEAR 2000
BOUNDARY OF REGIONAL WPCF DISTRICT
ROUTE OF MOLE TUNNEL CONDUCTING REGIONAL WPCF EFFLUENTS TO LAND APPLICATION SITES
FORCE MAIN TRANSPORTING TREATED WASTEWATER
DENOTES TYPE OF LAND APPLICATION METHOD SPRAY OR RAPID INFILTRATION WITH APPROXIMATE GROSS ACREAGE
DENOTES AVAILABLE LAND APPLICATION SITE

Figure 26

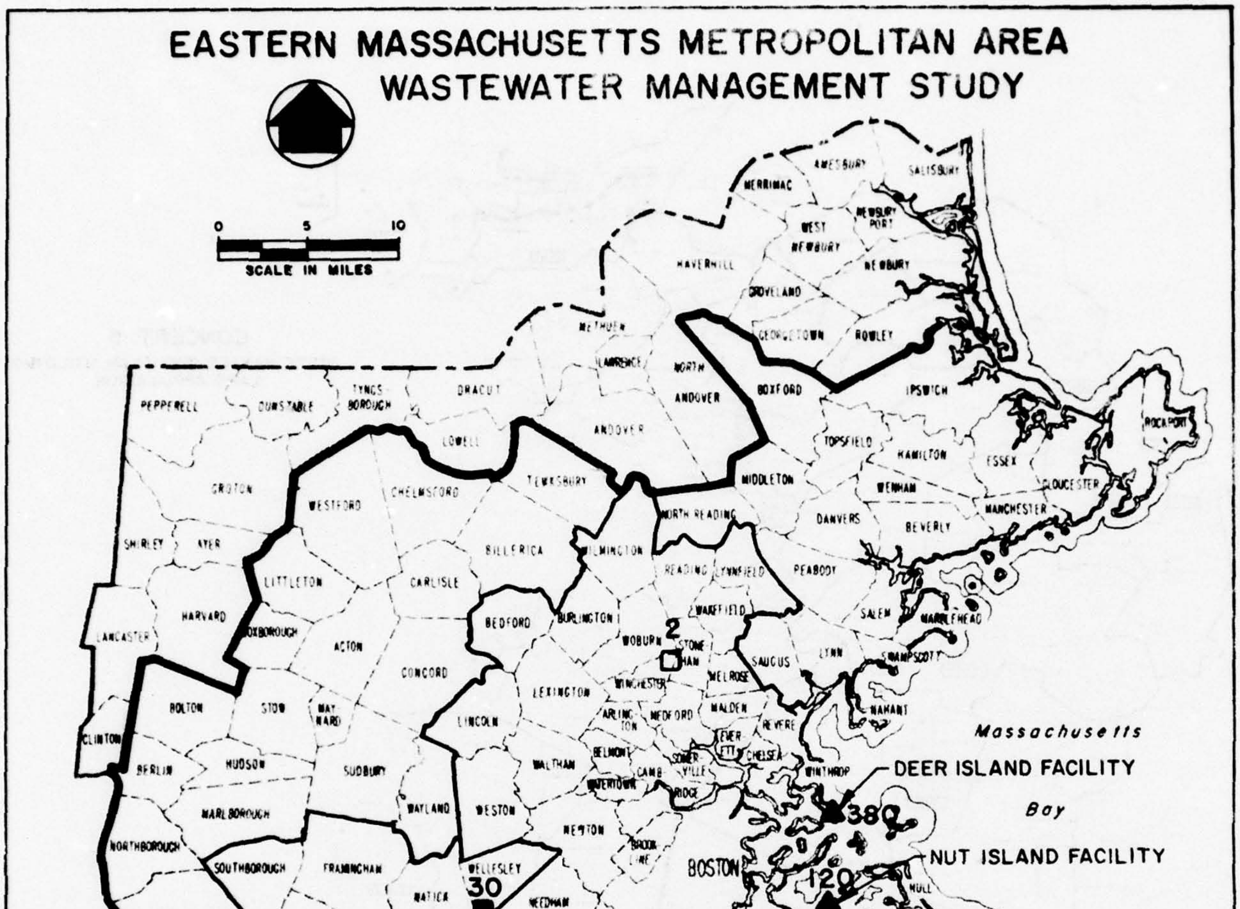

EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY
0 5 10
SCALE IN MILES
Massachusetts
Bay
DEER ISLAND FACILITY
NUT ISLAND FACILITY
BOSTON
380
120
30
30
4
4
8
2
Rhode Island
STUDY AREA BOUNDARY
RECOMMENDED SERVICE AREAS
120 APPROXIMATE CAPACITY OF THE FACILITY IN MGD
SECONDARY TREATMENT FACILITY
RECOMMENDED ADVANCED TREATMENT FACILITY
FLOW AUGMENTATION FACILITY

FIGURE 27

Control Act Amendments of 1972, to pretreat hazardous wastes to non-hazardous concentrations.

b. Elimination of other sources of pollution.

c. Reliability of the total system (large systems versus small systems).

d. Construction of treatment plants and collection systems.

4. Impacts of concept 6, the recommended alternative are presented separately, by river basin.

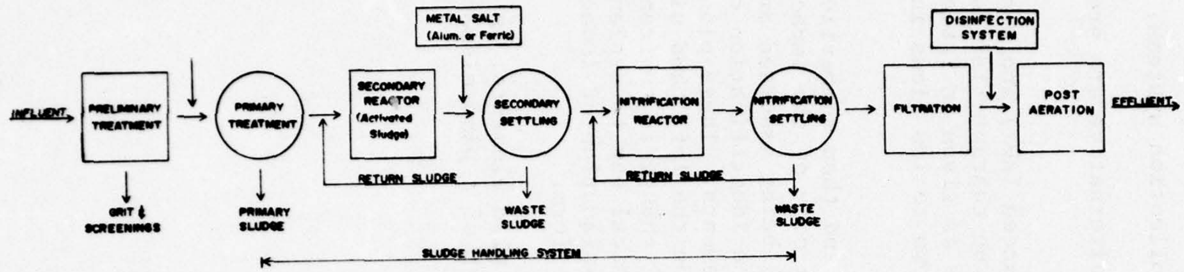
Figure 28 displays the flow sheets for advanced (AWT) and secondary treatment proposed by the MDC. Information on characteristics of secondary and advanced waste treatment effluents is given in Table 31, and a comparison of proposed treatment plant flows to low flows in each river basin is provided in Table 32.

Impacts for each river basin are discussed and then summarized on an impact assessment form. Figure 29 is a blank copy of the impact assessment form. The river basin and concept(s) being assessed are given in the upper left hand corner. Next to the identification of river basin and concept, is the list of plan elements. These plan elements relate to the numbered vertical lines on the left hand side of the page. If a plan element causes a particular change in environmental conditions, a dotted line is drawn from its vertical bar to explanations of change and impacts listed on the form. An explanation of impact symbols is given in the right hand corner of the form.

Mitigation measures are suggested for many plan elements, as it is felt that these measures may change the impact of a plan element in a beneficial manner.

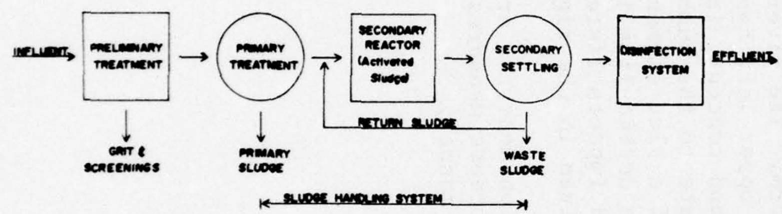
WASTEWATER TREATMENT PROPOSED

a.) ADVANCED WASTE TREATMENT



EXPECTED EFFLUENT QUALITY	MONTHLY AVERAGE
BOD_5	5mg/l
SS	5mg/l
NH_3-N	<1mg/l
PHOSPHOROUS AS P	<1mg/l
FECAL COLIFORM BACTERIA	200/100ml
pH	6.0-9.0

b.) SECONDARY TREATMENT



EXPECTED EFFLUENT QUALITY	MONTHLY AVERAGE	WEEKLY AVERAGE	REMARKS FOR BOD & SS
BOD (5day at 20°C)	30mg/l	45mg/l	OR 85% REMOVAL, WHICHEVER IS MORE STRINGENT
SS	30mg/l	45mg/l	
FECAL COLIFORM BACTERIA	200/100ml	400/100ml	
pH	6.0-9.0	6.0-9.0	

FIGURE 28

TABLE 31

Characteristics of Secondary and AWT Effluents*
(mg/l, monthly averages)

	Secondary[1]	AWT [2]
BOD	30	5
COD[5]	70	-
Total Nitrogen (ASN)	15-20	-
Organic Nitrogen (ASN)	2.0	-
Ammonia (NH_3-N)	9.8	1
Nitrite (NO_2-N)	0	-
Nitrate (NO_3-N)	8.2	-
Total Phosphorous	10	1
Suspended Solids	30	5
PH	6.0-9.0	6.0-9.0
Total Coliforms[3]	1000/100 ml	1000/100 ml
Fecal Coliforms	200/100 ml	200/100 ml

1. Data supplied by David Kenyon, U.S. Army Corps of Engineers
2. Expected effluent quality supplied by MDC
3. Assumes 99.999% reduction of coliforms (average coliform concentration of raw sewage = 1×10^8 per 100 ml.)

*Concentrations of heavy metals and organic chemicals are not listed as they will be removed through enforcement of industrial pretreatment requirements.

TABLE 32

COMPARISON OF PROPOSED TREATMENT PLANT FLOWS WITH 7 DAY-10 YEAR AND 7 DAY-2 YEAR LOW FLOWS

Receiving Stream and Location of Proposed STP	7 Day Low Flow with[1] 10 year occurrence (cfs)	7 Day Low Flow with[1] 2 year occurrence (cfs)	Flow of Proposed STP[2] 2000 (cfs)	2020 (cfs)	2050 (cfs)	Concept No.
Mystic R., Medford	2.8	6.6	46.4	52.6	49.5	4
Aberjona R., Woburn	1	1	48.0	49.5	49.5	4
Ipswich R., Middleton	1	2.9	3.7	6.7	9.4	1- 4
Ipswich R., Hamilton	1.9	5.9	2.2	10.1	17.0	1- 4
Neponset R., Canton	12	20	46.4	60.3	66.5	4
Neponset R., So. Canton	5.7	9.5	38.7	49.5	54.1	2
Neponset R., No. Canton	12	20	8.5	11.1	11.8	2
Charles R., Milford	1	1.8	5.7	7.1	7.3	1,2,4,5
Charles R., Medway	4.1	9.8	12.4	24.7	35.6	1,2,4,5
Charles R., Medfield	6.8	16	6.2	11.8	17.0	1,2,4,5
Charles R., Dedham	12	28	44.9	57.2	58.8	2
			34.0	43.3	44.9	4
Charles R., Waterown	11	25	69.6	78.9	78.9	2,4
Concord R., Concord	22	52	12.8	24.7	35.4	1-5
Sudbury R., Sudbury	4.2	10	8.4	20.1	24.8	1-5
Sudbury R., Framingham	1.2	3.0	29.4	38.7	46.4	2,4
Assabet R., Marlborough West	1.6	5.5	14.4	26.3	38.7	1-5
Assabet R., Hudson	2.4	8.0	6.0	10.1	17.0	1-5

1. River Flow data supplied by M. A. Slotkin, U.S. Army Corps of Engineers
2. STP Flow supplied by MDC

FIGURE 29

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area ____________ PLAN ELEMENTS

Concept ____________

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS	CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES

B. COMPUTATION OF HYGIENIC RELATED CHARACTERISTICS OF RECEIVING WATERS

Effluent characteristics of hygienic or public health concern are bacteria, viruses, nitrates and metals. These substances, when added to surface waters or groundwaters through treatment facility discharge, have an impact on the use of these waters in terms of hygienic safety.

The U.S. Environmental Protection Agency's Water Quality Criteria for raw water used for drinking water sets the maximum acceptable level for total coliforms at 10,000/100 ml and for nitrate nitrogen at 10 mg/l to protect the public health.

The new primary interim drinking water regulations currently being proposed in accordance with the Safe Drinking Water Act of 1974 set maximum acceptable levels for total coliforms in finished drinking water at 1/100 ml MF as an arithmetic mean for all samples taken in a month*, and for nitrate nitrogen at 10 mg/l. The Massachusetts Division of Water Pollution Control requires that waters used as sources of drinking water supplies (Class A waters) contain less than a monthly average of 50 coliform colonies/100 ml, and that waters used for contact recreation and as sources of water supplies with treatment and disinfection contain less than a monthly average of 1000 coliform colonies/100 ml.

No limits for viruses in drinking water, or water used for recreation have been prescribed because methods for routine monitoring have not been perfected, and there is a lack of data on virus die-off rates, correlation with existing indicators, as well as a lack of data which could lead to the selection of an indicator virus. However, viruses are a great health hazard when contaminating bathing waters and drinking water supplies, as many studies have found that 1 plaque forming unit (PFU) of virus is enough to cause disease in man.

There are Federal criteria and regulations for metals in drinking water. However, metals will not be addressed here, as the Federal Water Pollution Control Act Amendments of 1972, as well as Section 10, Chapter 83 of the Massachusetts General Laws, require that all municipal treatment facilities have sewer use ordinances which prohibit introduction by any discharger into a treatment facility of any pollutant which is toxic in toxic amounts, and which interferes with, passes through or is otherwise incompatible with the treatment process. Because of pretreatment requirements, metals discharged to waters in treatment facility effluents should not be a health hazard.

In this section an attempt is made to quantify changes in concentrations of bacteria, viruses and nitrates in waters receiving discharges from proposed waste treatment facilities.

* No one sample may exceed 4 colonies per 100 ml if 20 or less samples are taken, and no more than 5% of the samples may exceed 4 colonies per 100 ml if over 20 samples are taken.

1. Water-Oriented Concepts.

Total coliform concentrations in raw sewage have been estimated in the range of 10^6 - 10^9 coliform colonies /100 ml, and current total coliform counts of the influent to the Deer Island treatment facility range around 6.0×10^7/100 ml. Using an average estimate of total coliforms of 1×10^8 colonies/100 ml, and assuming a removal of 99.999% by disinfection (which is currently achieved at the Deer Island treatment facility), total coliform counts in advanced waste treatment effluent may be estimated at a maximum of 1000 colonies/100 ml. This is a maximum estimate as it does not take into consideration coliforms removed by other treatment processes, or natural die-off.

An estimation of change in fecal coliform concentrations would provide a better analysis of the health impacts of adding advanced waste treatment discharge to various streams, however little data exists on fecal coliform concentrations of the rivers in the study area.

Nitrate concentrations in advanced waste treatment effluent may be estimated at 19 mg/l. This assumes that secondary effluent contains 20 mg/l total nitrogen, most of which is in the form of ammonia and nitrate. If the nitrification process added to secondary treatment is designed to decreases the quantity of ammonia in the effluent by conversion to nitrate, to less than 1 mg/l, then it can be estimated that approximately 19 mg/l total nitrogen will be in the form of nitrate.

Estimation of virus concentrations in advanced waste facility effluent is considerably more difficult. Shuval, in a study of the virus content of raw sewage in Israel, found virus concentrations in raw sewage to range from 5 PFU/l to 11,000 PFU/l. An average virus concentration of 1050 PFU/l in raw sewage was found (40).

Studies of virus removal versus treatment method have found the activated sludge process to remove 88 to 99% of various viruses under laboratory conditions. Studies in the field have found lower removals (53 - 90%) (41). It will be assumed here that virus removal by the activated sludge process is 70%.

Shuval (42) found that chlorination of effluent from a 2-stage high rate filtration plant removed approximately 90% of echoviruses and 50% of polioviruses in the effluent at contact time 15 minutes and chlorine dosage of 11 ppm (current contact time at the Deer and Nut Island treatment facilities is 15 minutes, and chlorine dosage is, on the average, 11 ppm). Virus removal by filtration can vary from 0 to 90%, and removal by the nitrification process is unknown.

Assuming an influent virus concentration of approximately 1000 PFU/l, and 70% virus removal by activated sludge followed by 50% removal by chlorination (taking into account more resistant viruses such as the poliovirus), the effluent virus concentration may be estimated at 150 PFU/l. This is only a rough estimate as removal by various treatment processes varies with such factors as contact time, chemical and physical characteristics of the water, and kind and concentration of the

organism to be destroyed. Chang (43) estimates the virus concentration of moderately polluted water at 30 PFU/1.

Assuming that advanced waste treatment achieves effluent concentrations of 1000 colonies/100 ml total coliforms, 19 mg/1 nitrate-nitrogen, comparison of effluent characteristics to characteristics of receiving waters shows that discharge of advanced waste treatment effluent to portions of streams currently receiving no direct treatment facility discharge will decrease total coliform concentrations and increase nitrate concentrations in the stream. Table 33 lists total coliform counts and nitrate concentrations in portions of various rivers proposed to receive advanced waste treatment discharge.

If an effluent virus concentration of 150 PFU/1 is assumed, and all receiving waters are considered moderately polluted, thus containing an estimated virus concentration of 30 PFU/1, discharge of advanced waste treatment effluent to streams currently receiving no such discharges will increase virus concentrations in these streams

Changes in these parameters (total coliforms, viruses and nitrates) caused by a change from secondary to advanced treatment in a specific location are too complex to estimate, as many of these existing secondary treatment facilities are currently not functioning properly.

Estimated increases in nitrate and virus concentrations indicate the need for; 1) addition of denitrification to the treatment process and 2) replacement of chlorination by a more effective disinfection process such as ozonation, at nearly all proposed treatment facilities. (The effectiveness of various denitrification processes in the removal of nitrates from treatment facility effluent is discussed on page A-43, and the effectiveness of ozonation as a disinfection process is discussed on page A-38).

TABLE 33

Total Coliform And Nitrate Concentrations In Streams Receiving Advanced Waste Treatment Effluent, BH-EMMA Study Area

Proposed Treatment Facility	Receiving Stream	Characteristics of Receiving Waters*		Characteristics of AWT Effluent	
		NO_3^--N (ppm)	Total Coliforms (Range in colonies/100 ml)	NO_3^--N (ppm)	Total Coliforms per 100/ml
Woburn	Aberjona River	2.8	3500 - 9,500	19	1000
Medford	Mystic River	1.3	4800 - 20,000	19	1000
Canton (concept 4)	Neponset River	.40	5000 - 93,000	19	1000
Canton No.(concept 2)	Neponset River	.40	5000 - 93,000	19	1000
Canton So. "	Neponset River	.40	5000 - 93,000	19	1000
Dedham	Charles River	.23	1200 - 28,000	19	1000
Watertown	Charles River	.18	3000 - 120,000	19	1000
Hamilton	Ipswich River	.10	600 - 4,000	19	1000
Middleton	Ipswich River	.30	900 8,000	19	1000
Framingham	Sudbury River	.25	110,000 - 900,000	19	1000
Sudbury	Sudbury River	.20	2600 - 160,000	19	1000

*Nitrate and total coliform concentrations obtained from samples taken in 1973 by the Massachusetts Division of Water Pollution Control. Data is taken from sampling stations nearest to proposed treatment facility sites.

2. Land-Oriented Concepts

Again, effluent characteristics of public health concern are bacteria, viruses and nitrates.

Assuming secondary effluent characteristics given in Table 31, total coliform bacteria concentrations in the soil renovated effluent will be less than 10 colonies/100 ml assuming greater than 99% removal by the soil system (see page A-54). This concentration is considerably lower than the maxiumum acceptable level of 10,000 colonies/100 ml set by EPA's Water Quality Criteria for raw water used for drinking water.

Using the effluent virus concentration calculated in section B (page 122) of 150 PFU/l or 15 PFU/100 ml, virus concentrations in the soil renovated effluent will be less than .1/100 ml assuming greater than 99% removal by the soil system (see page A-54). Health impacts of such a virus concentration cannot be estimated as investigations in this field are inconclusive. In any case, groundwater supplies lying near land application sites would most probably be disinfected, causing greater virus removal.

Total nitrogen in the secondary effluent is assumed to be 20 mg/l consisting of organic-N (2 mg/l), ammonia-N (10 mg/l), and nitrate-N (8 mg/l). About 1.05 mg/l of the organic-N fraction is considered residual organic-nitrogen and is not readily available for crop utilization. The remaining 18.95 mg/l is essentially crop available nitrogen. Under normal agricultural practices, nitrogen loss due to denitrification must be accounted for which in this case is assumed to be 30 percent. A nitrogen loss of about 30 percent is a reasonable estimate at this time but the percentage lost may be higher under actual field conditions. Crop available nitrogen is, therefore, about 13.24 mg/l (44).

It is calculated in the Merrimack Wastewater Management Study, Appendix II that spray irrigation sites used to grow forage crops may remove all nitrogen applied at effluent application rates of 1.25 and 2.0 in/wk. Spray irrigation of 2.5 inches of effluent per week led to 60 to 80% removal of applied nitrogen, leaving 3.8 to 5.3 mg/l nitrogen available for movement through the soil during times of high precipitation or non-application. If all this nitrogen were in the form of nitrate, it should not cause levels of nitrate-N in groundwater to exceed 10 mg/l, the maximum acceptable level for drinking water supplies.

If the effluent is applied to forested areas nitrogen removal may be less.

Sopper (45) observed that 2-4 in/wk application of effluent to mixed hardwood forests resulted in 70-80% nitrogen removal during the initial two years of study; however removal decreased to 30-50% after 6 years. If crop available nitrogen is 13.3 mg/l, it can be calculated that a maximum approximately 4.0 mg/l nitrogen will be available for movement through the soil during initial years of application, and a

maximum of approximately 9.0 mg/l nitrogen will be available in years thereafter. If proper management practices, such as frequent harvesting, are regarded, the amount of nitrogen available for movement through the soil will be less. Even if all the 9 mg/l total nitrogen available for soil movement after 2 years of application were in the form of nitrate, it should not create a hazard to groundwater supplies through raising the nitrate concentration above the maximum acceptable level of 10 mg/l.

As for rapid infiltration sites, investigations at Flushing Meadows found that 70-80% nitrogen removal could be accomplished at an application rate of 3.2-8.6 gal/2 ft/day and an application cycle of 9 days application-5 days recovery (46). Studies at Fort Devens, Massachusetts found total nitrogen removal to be 40-60% under a 2 day application-14 day recovery cycle (47). Assuming a minimum nitrogen reduction of 40%, a maximum of 8 mg/l nitrogen will be available for movement through the soil. This concentration, also, should not present a hazard to groundwater used for drinking water supplies.

C. IMPACT ASSESSMENT

1. The No Action Alternative

Continuance of existing arrangements for wastewater management, and existing levels for waste treatment will have the following effects:

a. Boston Harbor

The continued practice of primary treatment at the two Harbor treatment facilities would have little effect on water quality. Improvement of water quality depends on elimination of ocean disposal of sludge, and elimination or mitigation of many non-point sources of pollution, such as combined sewer overflows, stormwater overflow, and wastes from ships.

If these facilities and their tributary collection systems are not expanded to accommodate higher flows from increased population in their service areas, treatment efficiency would decrease, and the probability of bypass would increase. This would have an adverse effect on water quality. The Nut Island facility is currently overloaded.

b. Mystic River Watershed

If no wastewater treatment facility discharge is added to the Mystic, there would be no change in water quality. Improvement in water quality depends on elimination of combined sewer overflows and solution of stratification problems on the Mystic, and elimination of industrial discharges, debris, and low flow on the Aberjona.

c. Neponset River Watershed

If no wastewater treatment facility discharge is added to the Neponset, there would be no change in water quality. Improvement in water quality again depends on elimination or mitigation of non-point sources. Recent efforts to clean up the Neponset and eliminate industrial discharges have already improved characteristics of the river.

Increased demand on Canton and Dedham water supply wells may cause lower flows in the river.

d. The Charles River Watershed

Maintaining the existing arrangement for wastewater management in the Charles may degrade the quality of the water.

Currently, four secondary waste treatment facilities in Milford, Medfield, Franklin and Millis discharge to the Upper Charles. These facilities are overloaded, and are not functioning at their design efficiency. Bacterial counts in this portion of the river are high. Secondary wastewater treatment does not remove adequate concentrations of nutrients to prevent excessive algal growth. The river is very slow moving in this area, thus accentuating these polluted conditions. If

treatment facilities are not expanded and upgraded conditions would become worse. However Medfield has just completed construction of a larger advanced waste treatment facility. And the towns of Franklin, Medway, Millis and Milford are in the process of making plans for advanced waste treatment. Improvement of water quality on the Upper Charles also depends on elimination of industrial discharges, pollution from malfunctioning subsurface disposal systems, and solution of low flow problems.

On the Middle Charles a decline in water quality would be expected. Flows may decrease due to an increased demand on groundwater supplies that are hydraulically connected to the river. Currently, towns supplied with water from wells along the Charles discharge their wastewater outside the Basin, at the two Harbor treatment facilities. Continuance of this situation would cause lower flows and unpleasant conditions.

If no waste treatment facility effluent is added to the Lower Charles, there would be no change in water quality. This portion of the river is increasingly polluted by combined sewer overflow and urban runoff. In addition, a deep layer of salt water on the rivers bottom is causing hydrogen sulfide odor problems. Improvement of water quality depends largely on the elimination or treatment of these sources of pollution.

e. South Coastal-North River Watershed

Continuance of existing arrangements for wastewater management and existing treatment levels in this watershed may degrade water quality.

Currently the town of Hull is discharging raw wastes to the ocean, and the town's unsewered portions are experiencing problems with subsurface disposal systems. Poor quality water is endangering bathing beaches, and has closed the town's shellfish harvesting areas. Further degradation of the water will occur if plans are not made for wastewater management. However the town is currently in the process of planning a secondary waste treatment facility.

The Rockland secondary treatment facility is currently degrading the quality of French Stream, which flows into the North River. The facility is not working at its design efficiency. Secondary treatment does not remove sufficient amounts of nutrients to prevent algal growth. High bacterial counts and excessive plant growth prevent recreational use of the stream and instream ponds.

Malfunctioning subsurface disposal systems are also degrading water quality below French Stream. If neither proper land use management nor municipal wastewater treatment are implemented, the quality of water in the river can be expected to decline.

f. North Coastal-Ipswich River Watershed

Most coastal towns in this area, with the exception of Swampscott and Manchester, have municipal sewerage systems which discharge raw wastes to the ocean. High bacterial counts in the north coastal waters prohibit bathing and shellfish harvesting in many areas. If municipal wastewater treatment is not provided conditions can be expected to get worse, as increased population will increase flows. Most of these towns are currently making plans for municipal wastewater treatment.

If no wastewater treatment facilities are provided to towns along the Ipswich, there would possibly be a decline in water quality. These towns currently have no municipal sewerage systems; portions of Wilmington, West Peabody, Middleton and North Reading are experiencing problems with individual subsurface disposal systems. Pollution from these malfunctioning systems and improperly located solid waste disposal sites, is threatening the quality of water supplies which are diverted from the river. Growing population in these towns may cause a greater deterioration of water quality. Proper land use management may be all that is needed to solve pollution problems.

If no wastewater treatment facility was provided to the town of Essex, water quality in the Essex River would decline. Subsurface disposal systems in the downtown portion of Essex are currently causing high coliform counts in the river, prohibiting shellfish harvesting.

g. The Sudbury, Assabet and Concord Watersheds (SUASCO)

Continuance of existing arrangements for wastewater management in SUASCO may cause degradation of water quality. Malfunctioning subsurface disposal systems in Acton along the Concord River and in Bolton, Berlin, and Boxborough, along the Assabet River and its tributaries, are degrading water quality. The towns of Westborough, Maynard and Shrewsbury are served by secondary municipal treatment facilities discharging to the Assabet. These facilities are not providing efficient treatment because they are overloaded due to infiltration, and secondary treatment does not provide adequate nutrient removal. Consequently the river is high in coliform counts and plagued by plant growth in some sections. The Billerica secondary treatment facility is also overloaded causing deterioration of Concord River quality.

If existing treatment facilities are not expanded or upgraded, and individual subsurface disposal systems continue to pollute the SUASCO rivers, conditions will become worse. In addition, increased development in towns, such as Sudbury and Wayland, along the Sudbury River, may lead to subsurface disposal system failure in these towns also. Proper land use management, and elimination of non-point sources such as improperly located solid waste disposal sites are needed on these rivers, as well as expansion and upgrading of existing treatment facilities, to prevent deterioration of water used for drinking and recreation.

h. **Areas Affected Outside the Study Area- Southeastern Massachusetts**

If land application of a portion of the study areas wastes is not implemented in southeastern Massachusetts environmental conditions would remain the same. Water quality problems in this area are related to local sources of pollution. It is possible that some towns in this area may use the land themselves for application and disposal of wastewater, thus eliminating direct effluent discharge to surface waters.

2. Concepts 1 Through 5

a. Boston Harbor

All five concepts propose to upgrade treatment at the two MDC wastewater treatment facilities at Deer and Nut Islands from primary to secondary treatment. These treatment facilities currently serve 43 communities in the Boston area. In concepts 1 and 3, the area served by the two harbor treatment plants would be expanded. Concept 1 proposes minimum expansion to ultimately serve 50 communities. Concept 3 proposes maximum expansion to serve communities of the Upper Charles and communities surrounding the MDC water supply reservoir in the Sudbury River Watershed. Under concept 3, Deer and Nut Island treatment facilities would ultimately serve 58 cities and towns in eastern Massachusetts. In concepts 2, 4, and 5 the service areas tributary to the Deer and Nut Island treatment facilities would be reduced. Concept 2 proposes a service area of 32 communities, and concepts 4 and 5 propose a service area of 24 communities. Communities proposed to be detached from the present Deer and Nut Island service area would be serviced by regional facilities.

Upgrading the two Harbor treatment facilities from primary to secondary treatment will have minimal impact on the quality of the water in the Harbor. There may be a slight decrease in bacterial concentrations due to removal of substances that interfere with the disinfection process. However coliform bacteria removal at both plants is currently over 99 percent. Concentrations of some metals in the treatment plant effluent will be decreased due to improved treatment and stricter pretreatment requirements.

Expansion of the service area under concepts 1 and 3 would require expansion of the treatment facilities to accommodate increased flow. Expansion of the Nut Island facility is particularly important, as current flows through this plant already exceed design flow. Concepts 1 and 3 also require extension of the sewer systems. Extension of collection systems to unsewered areas experiencing problems with individual subsurface disposal systems would eliminate some water pollution problems in watersheds tributary to the Harbor. However larger treatment facilities and collection systems pose a greater pollution threat when they are not functioning properly.

Concepts 2, 4 and 5 would require smaller treatment facilities and collection systems which would be a lesser hazard when malfunctioning.

All concepts address the Harbors major pollution problems of sludge disposal, combined sewer overflow, and stormwater runoff. These problems are also addressed in the permits issued to the MDC and the city of Boston by the U.S. Environmental Protection Agency and the Division of Water Pollution Control. These permits require that the MDC submit plans for sludge disposal: and that both the MDC and city of Boston submit a sewer use ordinance and plans for minimization of combined sewer overflows and bypasses.

In summary, implementation of secondary treatment at Harbor treatment facilities would make little change in the Harbors recreation or shellfish harvesting areas. Improvement in water quality largely depends on elimination or mitigation of other sources of pollution. Differences in impacts among the four concepts is mainly due to differences in the size of service areas. Smaller facilities and sewer systems proposed in concepts 2, 4, and 5 would cause less pollution when not functioning properly.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Boston Harbor

Concept 1, 3

PLAN ELEMENTS

1. Change from primary to secondary treatment.
2. Expansion of service area *

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.	2.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
●		+L	Slight decrease in bacterial concentratons, as improved treatment may remove substances that interfere with disinfection. However, there is still a problem of bacteria from other sources.	Slight decreased hazard to recreation and shellfish areas.	Elimination or treatment of other sources of pollution.
●		+L	Slight decrease in metals concentrations due to improved treatment.	Slight decreased hazard to shellfish areas.	
	●	+L	Elimination or pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas and water supplies in areas surrounding the harbor.	
	●	-S	Larger treatment plants and more extensive collection systems cause more pollution when malfunctioning.	Increased hazard to recreation areas and water supplies.	
●	●	-S	Construction may temporarily degrade water quality.	Increased hazard to recreation areas and water supplies.	

* Concept 1 - Services 50 communities by the year 2000
Concept 3 - Services 58 communities by the year 2000

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: Boston Harbor

Concept: 2, 4, 5

PLAN ELEMENTS

1. Change from primary to secondary treatment
2. Reduction of service area *

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS (1, 2)		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1	+L	Slight decrease in bacterial concentrations, as improved treatment may remove substances that interfere with disinfection. However, there is still a problem of bacteria from other sources.	Slight decreased hazard to recreation and shellfish areas.	Elimination or treatment of other sources of pollution.
1	+L	Slight decrease in concentrations of hazardous substances, such as metals due to improved treatment.	Slight decreased hazard to recreation and shellfish areas.	
2	+L	Smaller treatment plants and less extensive collection systems cause less pollution than larger systems when they are not functioning properly.	Decreased hazard to recreation and shellfish areas.	
1, 2	-S	Construction may temporarily degrade water quality.	Increased hazard to recreation and shellfish areas.	

*Concept 2 - Services 32 communities by the year 2000
Concepts 4 and 5 - Services 24 communities by the year 2000

b. Mystic River Watershed

Concepts 1, 2 and 3 essentially propose continuance of existing conditions with respect to wastewater management in the Mystic River Watershed. The collection system tributary to Deer Island treatment plant would probably be expanded to accommodate areas that are currently experiencing problems with subsurface disposal systems. Although an expanded system may eliminate pollution from faulty individual systems, it may present a greater pollution hazard when malfunctioning. These concepts do not address elimination of other sources of pollution or flow augmentation. Low flow is a particular problem on the Aberjona River, where unsightly conditions exist during summer months.

In summary, implementation of these concepts would cause only minor water quality changes in the Mystic Watershed. Impacts of Concept 5 would be the same as those of concepts 1, 2, or 3 as effluent from regional facilities would be transported outside the watershed.

Concept 4 proposes 2 regional advanced waste treatment facilities. One facility, located in Medford would discharge 30 MGD to the Mystic River, below Alewife Brook. The flow from this plant would be approximately 15 times the 7 day low flow with a 10 year recurrence at this point in the river, and 7 times the 7 day-2 year low flow. Thus, at times, a great percentage of flow in the river would be treatment plant effluent. Bacterial comcentrations in the effluent (1000/100 ml) would be much lower than concentrations in the river (400-240,000/100 ml), creating less health hazards to people using the river for recreation. BOD concentrations in the effluent may also be lower than BOD concentrations in the river.

However, because the proposed treatment process includes nitrification with no denitrification, there would be an increase in nitrate concentrations in the river due to the discharge of such a large quantity of effluent. High concentrations of nitrate, in combination with levels of nitrate and phosphorous already present in the river may promote algal growth, which may lead to stagnant, odorous conditions. Such unpleasant conditions already exist for two reasons. First of all, this portion of the Mystic is very slow moving, and nutrients from other sources, such as combined sewer overflows to Alewife Brook (just above proposed treatment facility site), are not flushed out rapidly. Secondly the Lower Mystic Basin is highly stratified with a deep layer of salt water at the bottom. This layer of salt water contributes to odorous conditions by supporting a large population of hydrogen-sulfide producing anaerobic bacteria.

Addition of denitrification to the proposed treatment process, and elimination of other sources of pollution would mitigate adverse effects of an advanced waste treatment discharge to the Mystic at Medford.

The other advanced waste treatment facility would be located on the Aberjona River in Woburn. Flow on the Aberjona River often reaches less than 1 cfs in the summer months. Also, average flow at a point

2.5 miles above the proposed treatment plant site is 27 cfs. The proposed treatment facility flow of 31 MGD (48 cfs) would constitute a major portion of the flow, expecially during summer months.

Addition of such a large quantity of advanced waste treatment effluent would be beneficial as it would eliminate unsightly conditions, and flush out the river during summer. Concentrations of coliform bacteria, BOD and ammonia in the river may be higher in river water than in treatment plant effluent. Dilution of these pollutants would create more pleasant conditions for those living along the river, and present less health hazards for those using the river for recreation. However, concentrations of nitrates may be increased, as the proposed treatment does not include denitrification. High levels of nitrates, in combination with high levels of nutrients that already exist in the Aberjona may promote algal growth, which lead to unsightly odorous conditions. High nutrient concentrations may also be a threat to the Upper Mystic Lake, (below the proposed treatment facility site), which is used by people in the Boston area for both contact and non-contact recreation. This lake is already subject to eutrophic conditions in summer.

The location of the treatment facility above the Upper Mystic Lake may also be a public health hazard in the event of treatment failure. High concentrations of bacteria and viruses would be a threat to swimmers, and higher concentrations of nutrients would stimulate greater plant growth.

Again, adverse effects of this advanced waste treatment discharge could be mitigated by addition of denitrification to the treatment process, employment of ozonation rather than chlorination as a disinfection process and elimination of other sources of pollution.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: Mystic River

Concept: 1, 2, 3, 5

PLAN ELEMENTS

1. Extension of collection system

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
O Problematical impact

PLAN ELEMENTS		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1.	+L	Elimination of pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas and water supplies	
1.	-S	Larger, more extensive collection systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and water supplies.	
1.	-S	Construction could temporarily degrade water quality	Temporary increased hazard to recreation areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA WASTEWATER MANAGEMENT STUDY

Area: Mystic River

Concept: 4

PLAN ELEMENTS

1. AWT - Woburn
2. AWT - Medford
3. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.2.3.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
	+L	Decrease in bacterial concentrations, as treatment plant effluent will constitute a major portion of river flow during periods of low flow. (Compare bacterial concentrations in the Mystic and Aberjona, Table 16 to bacterial concentrations in AWT effluent, Table 31).	Decreased hazard to recreation areas; however, it would not be advisable to swim in water that is largely treatment plant effluent (see below).	
	-L	Possible increase in virus concentrations by adding such a large quantity of treatment plant effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas.	More effective disinfection process such as ozonation
	0	Decrease in oxygen demand in Aberjona and Mystic Rivers due to discharge of such a large quantity of effluent with lower concentrations of ammonia and BOD than some portions of the River (Compare Table 16 to Table 31), thus promoting less stagnant and odorous conditions. However increase in nitrates due to nitrification, in combination with present phosphorous levels, may cause algal blooms, and promote stagnant conditions.	Unknown impact depending on whether concentrations of nitrates and phosphates will increase or decrease algal blooms.	Denitrification to remove nitrates.
	+L	*Elimination of pollution in areas with subsurface disposal* problems.	Decreased hazard to water supplies and recreation areas	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Mystic River

Concept 4 (continued)

PLAN ELEMENTS
1. AWT - Woburn
2. AWT - Medford
3. Extension of collection systems

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term

PLAN ELEMENTS 1. 2. 3.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
● ● ●	-S	Large treatment plants in locations where there are presently none and larger collection systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas such as the upper Mystic Lake	
● ● ●	-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

c. Neponset River Watershed

Concepts 1 and 3 propose continuance of existing conditions with respect to wastewater management in the Neponset River Watershed. Extension of collection systems to unsewered areas may eliminate pollution due to failure of individual subsurface disposal systems. However larger, more extensive collection systems may present a greater health hazard to recreation areas and water supplies when not functioning properly. Impacts of concept 5 would be the same as concepts 1 and 3 as concept 5 also proposes discharge of wastewater outside the watershed. Implementation of these concepts would produce little change in the quality of water in the Neponset.

Concept 2 proposes 2 regional advanced waste treatment facilities on the Neponset. One of these facilities would be located in North Canton near the Boston city line discharging 5.5 MGD (or 8.5 cfs) to the Neponset below the Fowl Meadow Marsh Area, and the other facility would be located in South Canton discharging 25 MGD (or 38.7 cfs) to the Neponset just above its confluence with the East Branch River. Flow from the North Canton facility would be approximately .75 times the 7 day low flow with a 10 year recurrence and .45 times the 7 day-2 year low flow. Flow from the South Canton facility would be approximately 6.5 times the 7 day-10 year low flow and 4 times the 7 day-2 year low flow.

Discharge of advanced waste treatment effluent to the Neponset would cause concentrations of coliform bacteria to decrease as the maximum effluent coliform concentration (1000/100 ml) would be less than concentrations in this stretch of the river (up to 93,000/100 ml). However concentrations of ammonia and nutrients in the river at both points may be less than such concentrations in the treatment facility effluent. Discharge of an effluent of the quality proposed by the MDC would thus have an adverse effect on the river, as increased nutrients may promote algal growth and unpleasant conditions. Also, as chlorination is the proposed method of disinfection, all viruses will not be removed and virus concentrations in the river may increase.

High nitrate and virus levels in the river from the South Canton facility may endanger present and potential groundwater supplies in the Fowl Meadow Marsh area, as the aquifer underlying the marsh is unified with the river, and a lowering of the water table can cause pollutants from the river to percolate into the groundwater. Any breakdown in treatment efficiency at the two facilities would also be a hazard to groundwater supplies if high concentrations of bacteria and viruses in the effluent caused concentrations of these organisms to increase in the groundwater.

Concept 4 proposes one regional advanced waste facility in Canton, discharging to the Neponset above Ponkapoag Brook. Effluent flow from this facility would be 30 MGD (46.4 cfs), or approximately 4 times the 7 day-10 year low flow and 2.3 times the 7 day-2 year low flow. Adverse and beneficial effects that would result from the implementation of concept 2 also apply to concept 4, although the impact of

concept 4 would be more intense than concept 2, as it proposes a larger flow from one facility.

Adverse effects would be mitigated by addition of denitrification to the treatment process, and employment of ozonation instead of chlorination, as a disinfection process.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA WASTEWATER MANAGEMENT STUDY

Area Neponset River

Concept 1, 3, 5

PLAN ELEMENTS

1. Extension of collection system

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1	+L	Elimination of pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas and water supplies.	
1	-S	Larger, more extensive collection systems cause more pollution when not functioning properly.	Increased hazard to recreation areas and water supplies.	
1	-S	Construction may temporarily degrade water quality.	Increased hazard to recreation areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: Neponset River

Concept: 2

PLAN ELEMENTS
1. AWT North Canton
2. AWT South Canton
3. Extension of collection systems

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.2.3.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1, 2	+L	Decrease in bacterial concentrations, as AWT effluent will constitute a large portion of the flow at both sites during periods of low flow. (Compare bacterial concentrations in Neponset, Table 19, to bacterial concentrations in AWT effluent, Table 31).	Decreased hazards to recreation areas. However, it would not be advisable to swim in water that is largely treatment plant effluent (see below).	
1, 2	-L	Possible increase in virus concentrations by adding such a large quantity of effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas and water supply wells in in Fowl Meadow.	More effective disinfection process, such as ozonation.
1, 2	-L	Increase in concentrations of nitrates due to nitrification of effluent may in combination with present phosphorous levels, promote algal blooms in many areas, leading to stagnant odorous conditions.	Unpleasant conditions at recreation areas.	Denitrification to remove nitrates.
1, 2	-L	Increase in concentrations of nitrates may increase nitrate concentrations in ground water supplies of Canton and Dedham in Fowl Meadow Marsh.	Increased hazard to water supplies.	Denitrification to remove nitrates.
3	+L	Elimination of pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas and water supplies.	
1, 2	-S	Locating treatment plants where there are presently none can cause short term degradation of water quality when a plant is malfunctioning.	Temporary increased hazard to recreation areas and ground water supplies in Fowl Meadow.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Neponset River

Concept 2 (cont'd)

PLAN ELEMENTS

1. AWT North Canton
2. AWT South Canton
2. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.2.3.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
3.	-S	*More extensive collection systems cause more pollution when malfunctioning.*	*Temporary increased hazard to* recreation areas and water supplies.	
1. 2. 3.	-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: Neponset River

Concept: 4

PLAN ELEMENTS
1. AWT Canton
2. Extension of collection system

EXPLANATION OF IMPACTS
- +L Beneficial impact-long term
- -L Adverse impact-long term
- +S Beneficial impact-short term
- -S Adverse impact-short term
- 0 Problematical impact

PLAN ELEMENTS (1. 2.)		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1	+L	Decrease in bacterial concentrations as AWT effluent will constitute a large portion of the flow at this site during periods of low flow. (Compare bacterial concentrations in the Neponset Table 19 to bacterial concentrations in AWT effluent). (More bacterial reduction than in Concept 2).	Decreased hazard to recreation areas, however it would not be advisable to swim in water that is largely treatment plant effluent (see below).	
1	-L	Possible increase in virus concentration by adding such a large quantity of effluent to the river as chlorination does not revove all viruses. (Greater increase than in Concept 2).	Increased hazard to recreation areas.	More effective disinfection process, such as ozonation.
1	-L	Increase in nitrates due to nitrification may, in combination with present phosphorous levels, lead to algal blooms, and stagnant odorous conditions. (Greater increase than in Concept 2).	Unpleasant conditions at recreation areas.	Denitrification to remove nitrates
1	-L	Increase in nitrate levels may increase nitrate concentrations in ground water supplies of Canton and Dedham in Fowl Meadow. (Greater increase than Concept 2).	Increased hazard to water supplies	Denitrification to remove nitrates

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: Neponset River

Concept: 4 (cont'd)

PLAN ELEMENTS
1. AWT Canton
2. Extension of collection systems

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1.2.	+L	Elimination of pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas and water supplies.	
1.2.	-S	Larger treatment plants, especially in locations where there are presently none, and more extensive collection systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and groundwater supplies in Fowl Meadow Marsh.	
1.2.	-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

d. Charles River Watershed

In the Charles River Watershed, proposed concepts range from maximum centralization, with all wastes from communities in the watershed being treated by the two Harbor treatment facilities, to a decentralized plan, with the location of 5 advanced waste treatment facilities in the watershed.

Concept 1 basically proposes the continuance of existing arrangements. Four existing municipal secondary treatment facilities in Milford, Medfield, Franklin and Millis would be upgraded or replaced by 2 advanced waste treatment facilities in Medway and Medfield, and one municipal advanced waste treatment facility in Milford. Total flow from these facilities would be 15.7 MGD (or 24.3 cfs). Upgrading treatment of wastes from these Upper Charles communities would have a beneficial effect on water quality. Portions of the Upper Charles River are presently severely degraded due to discharge of inadequately treated municipal wastewater, industrial discharge, leachate from solid waste disposal sites and overflow from faulty subsurface disposal systems. Concentrations of bacteria, BOD, ammonia, and nutrients are high, especially in areas downstream from treatment facilities. The proposed discharges of advanced waste treatment effluent would decrease coliform bacteria concentrations (which are presently in the millions per 100 ml), and decrease levels of oxygen demanding wastes and phosphorus. However concentrations of nitrates may increase, as the proposed treatment process includes nitrification with no denitrification. High concentrations of nitrates may stimulate algal growth.

If denitrification were added to the treatment process, progress toward a Class B water quality would be made by reducing health hazards created by high counts of bacteria, and establishing more pleasant conditions for those using the river by decreasing concentrations of nutrients which promote excessive algal growth and lower dissolved oxygen levels.

The increased service area of these facilities on the Upper Charles would also eliminate pollution from malfunctioning subsurface disposal systems. However larger collection systems and facilities may be a greater health hazard when not functioning properly.

Impacts of concept 5 would be similar to concept 1; although concept 5 proposes 5 treatment facilities on the Charles, only 3 of the facilities on the Upper Charles would be discharging to the river. Although implementation of concept 1 and 5 would improve water quality in this portion of the Charles, total achievement of Class B water would depend on elimination of pollution from other sources.

Concepts 2 and 4 propose decentralization of waste treatment on the Charles. In addition to the three advanced waste facilities proposed in concept 1, two more regional advanced waste treatment facilities would be located on the Charles River. One such facility would discharge

29 MGD, (or 45 cfs) in concept 2, or 22 MGD (or 34 cfs) in concept 4, to the Charles in Dedham. Flow from the treatment facility in Dedham under either concept would be approximately 3 to 4 times the 7 day-10 year low flow and 1.2 to 1.6 the 7 day-2 year low flow.

Addition of such a large quantity of effluent at this point would dilute concentrations of coliform bacteria (which are presently as high as 28,000/100 ml). However concentrations of nitrates would increase, as the proposed treatment does not include denitrification. Increased nitrate levels, in combination with nutrient levels already present in the river may increase algal growth. Two ponds along this section are currently in danger of becoming choked with plant growth. Further eutrophication would deplete dissolved oxygen levels, creating more unpleasant conditions to those living along and using the river. Concentrations of viruses may also increase, as chlorination does not remove all viruses. High virus concentrations would be a hazard to those using the river for recreation.

The other facility, proposed by concepts 2 and 4, would discharge 45 MGD (or 69.6 cfs) to the Charles just below Watertown Dam. The proposed treatment facility flow would be over 6 times the 7 day-10 year low flow of the river at this point, and over 2.5 times the 7 day-2 year low flow. Water in the Charles River Basin below Watertown Dam is currently severely degraded due to combined sewer overflows, urban runoff and a deep bottom layer of salt water that contains high concentrations of nutrients and a large population of hydrogen-sulfide producing anaerobic bacteria. The effects of treatment plant effluent would probably be neglibible in comparison to the effects of pollution from other sources. However, assuming pollution from other sources will be mitigated or eliminated in the future, the proposed treatment facility discharge in Watertown would have an adverse effect. The Charles River below Watertown Dam is extremely slow moving. Addition of nutrients through treatment facility discharge would promote eutrophication, and more stagnant, odorous conditions, making the Basin as undesirable as it is today for large scale recreation.

Adverse effects of the Dedham and Watertown facilities would be mitigated by addition of denitrification to the proposed treatment processes and employment of ozonation as a disinfection process. Achievement of Class B water quality above Watertown Dam, and Class C water quality below the Dam cannot be realized by actions proposed in concepts 2 and 4. Elimination of other sources of pollution along the river would have a greater beneficial impact on water quality.

Concept 3 proposes that the entire Charles River Watershed be serviced by the two Harbor waste treatment facilities. Such a plan would augment low flow problems in the Charles. Currently over 15 MGD of water, withdrawn from the watershed to supply water to the towns of Dedham, Westwood, Needham, Wellesley, and Cambridge, is finally discharged to Boston Harbor through the Metropolitan Sewerage System. In addition one third of the rivers flow at Dedham is diverted to the

Neponset River through the Mother Brook diversion. Adding towns on the Upper Charles to the Nut Island service area would decrease flow in the river and deplete groundwater supplies. Concentrations of pollutants from other sources in the river would increase due to lack of dilution water, and portions of the river would probably dry up during summer months, leaving pools of stagnant, odorous water. Implementation of this concept would create unpleasant conditions for both those living along the upper portions of the Charles, and those using the river for recreation. In addition, the larger more extensive collection systems for the Harbor treatment facilities would present a greater health hazard when not functioning properly.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Charles River

Concept 1, 5

PLAN ELEMENTS

1. Change from secondary treatment to AWT-Milford
2. AWT-Medway
3. Change from secondary treatment to AWT-Medfield
4. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS (1.2.3.4.)		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1, 2, 3, 4	+L	Decrease in bacterial concentrations, as improved treatment will remove substances that interfere with disinfection.	Decreased hazard to recreation areas.	
1, 2, 3	0	Lower concentrations of organic matter and ammonia resulting from improved treatment will decrease depletion of oxygen; however, increased concentrations of nitrates due to nitrification may increase algal blooms and result in depletion of oxygen and stagnant conditions.	Unknown impact depending on whether concentrations of nitrates and phosphorus increase or decrease algal blooms.	Denitrification to remove nitrates.
4	+L	Elimination of pollution from malfunctioning subsurface disposal systems, and possible elimination of pollution from institutions along the Charles and Stop Rivers.	Decreased hazard to recreation areas and water supplies.	
1, 2, 3, 4	-S	Larger treatment plants, and more extensive collection systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and water supplies.	
1, 2, 3, 4	-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Charles River

Concept 2.4

PLAN ELEMENTS
1. Change from secondary treatment to AWT-Milford
2. AWT-Medway
3. Change from secondary treatment to AWT-Medfield
4. AWT-Dedham
5. AWT-Watertown
6. Extension of collection systems

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.2.3.4.5.6.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1, 2, 3	+L	Decrease in bacterial concentrations as improved treatment may remove substances that interfere with disinfection.	Decreased hazard to recreation areas.	
1, 2, 3	0	Lower concentrations of organic matter and ammonia resulting from improved treatment will decrease the depletion of oxygen and decrease stagnant, odorous conditions. However, increase in nitrates concentrations due to nitrification may increase algal blooms, which can lead to depletion of oxygen, and stagnant conditions .	Unknown impact depending on whether concentrations of nitrogen and phospherus will decrease or promote algal blooms.	Denitrification to remove nitrates.
4, 5	+L	Decrease in bacterial concentrations in the water as AWT effluent will constitute a major portion of the flow at these sites during periods of low flow. Compare water water quality of the Charles, Table 21 to quality of AWT effluent, Table 31.	Decreased hazard to recreation areas. However, it would not be advisable to swim in water that is largely treatment plant effluent (see below).	
4, 5	-L	Possible increase in virus concentrations by adding such a large quantity of effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas.	More effective disinfection process, such as ozonation
4, 5	-L	Increase in nitrates due to nitrification, in combination with present phosphorous levels, may increase algal blooms leading to depletion of oxygen, and stagnant, odorous conditions.	Unpleasant conditions at recreation areas.	Denitrification to remove nitrates.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Charles River (Cont'd)

Concept 2,4

PLAN ELEMENTS

1. Change from secondary treatment to AWT-Milford
2. AWT-Medway
3. Change from secondary treatment to AWT-Medfield
4. AWT-Dedham
5. AWT-Watertown
6. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.	2.	3.	4.	5.	6.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
●	●	●				+L	Possible elimination of pollution from institutions along the Charles and Stop Rivers.	Decreased hazard to recreation areas.	
					●	+L	Elimination of pollution in areas with subsurface disposal problems	Decreased hazard to recreation areas and water supplies.	
●	●	●	●	●		-S	Large treatment plants, especially in areas where there are presently none, and larger collection systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and water supplies	
●	●	●	●	●	●	+S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: Charles River

Concept: 3

PLAN ELEMENTS
1. Wastewater from all towns transported to MDC facilities, Boston Harbor.
2. Extension of collection systems.

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.2.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1	+L	Elimination of municipal treatment plants that are presently malfunctioning, resulting in lower concentrations of bacteria, organic compounds, and nutrients. Such substances are currently causing stagnant conditions by depletion of oxygen, and promotion of algal blooms in many areas.	Possible decreased hazard to recreation areas, and possible elimination of unpleasant conditions; however, other factors must be considered (see below).	
1	-L	Lower flow from lack of recharge may produce stagnant, odorous conditions.	Increase in unpleasant conditions at recreation areas.	
2	-S	Larger sewerage systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and water supplies.	
2	-S	Construction of collection systems may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

e. South Coastal-North River Watershed

All concepts propose the same plans for the South Coastal-North River Watershed. The Rockland treatment facility, which currently discharges secondary effluent to French Stream would be upgraded to advanced waste treatment, and the existing Marshfield treatment facility would be expanded and upgraded from primary to secondary treatment. A secondary treatment facility would be built for Hull; the existing facility in Cohasset would be expanded to include part of Scituate and the existing facility in Scituate would be expanded to include Norwell, Pembroke, Hanover, and parts of Marshfield and Hanson. Many aspects of these plans are beneficial. The Rockland treatment facility is currently overloaded, and French Stream is very high in concentrations of coliform bacteria, BOD, ammonia (as high as 10 mg/l) and phosphorus (as high as 5 mg/l). Upgrading the treatment at this facility would decrease coliform concentrations, increase dissolved oxygen levels, and possibly decrease plant growth. This stream, which is presently very stagnant, odorous and euthropic in many portions, would be safer in terms of public health and more pleasant for both contact and non-contact recreation.

However, nitrate levels in French Stream may increase, as the proposed treatment does not include denitrification. High nitrate concentrations in combination with nutrients from other sources may stimulate plant growth, and perpetuate existing unpleasant conditions for those using the stream. Further study is needed to determine the need for denitrification of the Rockland facility effluent.

A secondary treatment plant in Hull would decrease health hazards to bathers on Hull beaches, and may possibly open some closed shellfish beds. Currently Hull discharges raw sewage into Boston Harbor and Massachusetts Bay through five discharge points. A secondary treatment plant in Hull would decrease concentrations of bacteria, BOD and suspended solids. In addition to eliminating raw municipal discharges, the facility would also eliminate pollution from the towns many malfunctioning subsurface disposal systems.

Expanding the Cohasset, Scituate and Marshfield facilities would be beneficial to areas such as parts of Norwell and Pembroke which are already experiencing subsurface disposal problems. However larger plants may endanger bathing and shellfish harvesting areas when not functioning properly.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA WASTEWATER MANAGEMENT STUDY

Area: South Coastal-North River

Concept: 1,2,3,4,5

PLAN ELEMENTS
1. Change from secondary treatment to AWT-Rockland
2. Change from no treatment to secondary-Hull
3. Change from primary to secondary treatment-Marshfield
4. Expansion of existing Cohasset and Scituate facilities
5. Extension of collection systems

EXPLANATION OF IMPACTS
- +L Beneficial impact-long term
- -L Adverse impact-long term
- +S Beneficial impact-short term
- -S Adverse impact-short term
- 0 Problematical impact

PLAN ELEMENTS 1.2.3.4.5.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1	+L	Decrease of bacterial concentrations from improved treatment, and discharge of AWT effluent that will constitute a major portion of the flow in French Stream. (Compare bacterial concentrations in French Stream, Table 24 to bacterial concentrations in AWT effluent, Table 31).	Decreased hazard to recreation areas.	
1	0	Decrease in oxygen demand in French Stream due to discharge of such a large quantity of effluent with lower concentrations of BOD and ammonia than the water in French Stream (Compare Table 24 to Table 31), thus promoting less stagnant, odorous conditions. However, the increase in nitrates from nitrification may, in combination with present phosphorus levels, promote more algal blooms, which can increase oxygen demand in the stream, and increase stagnant conditions.	Unknown impact depending on whether concentrations of nitrates and phosphorous will increase or decrease algal blooms.	Denitrification to remove nitrates.
2	+L	Great decrease in concentrations of hazardous substances, especially bacteria, as the present discharge receives no treatment, and there are no controls on the systems.	Decreased hazard to Hull beaches and shellfish areas.	
3, 4	+L	Decrease in bacterial concentrations due to removal of substances that interfere with disinfection, and slight reduction in other hazardous substances.	Decreased hazard to Marshfield beaches and shellfish areas.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area South Coastal- North River

Concept 1,2,3,4,5 (cont'd)

PLAN ELEMENTS
1. Change from secondary treatment to AWT-Rockland
2. Change from no treatment to secondary-Hull
3. Change from primary to secondary treatment-Marshfield
4. Extension of collection system

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.	2.	3.	4.	5.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
			●		+L	Elimination of pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas. shellfish areas, and water supplies.	
●	●	●	●		-S	Larger treatment plants and more extensive collection systems cause more pollution when malfunctioning.	Temporary inc reased hazard to recreation areas and water supplies.	
●	●	●	●		-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

f. North Coastal-Ipswich River Watershed

Concepts 1-4 propose the same plans for the North Coastal-Ipswich River Watershed.

Two advanced waste treatment facilities would be located along the Ipswich River. One facility would be located in Middleton, discharging 2.4 MGD (or 3.7 cfs) to the Ipswich. This flow would be 4 times the rivers 7 day-10 year low flow and 1.3 times the rivers 7 day-2 year low flow. The second facility would be located in Hamilton, discharging 1.4 MGD (or 2.2 cfs) to the Ipswich. This flow would be a little more than the rivers 7 day-10 year low flow and approximately one third of the rivers 7 day-2 year low flow.

The Ipswich River is currently of a marginal B quality. Adding such a large quantity of advanced waste treatment effluent to the River, especially in Middleton, may increase concentrations of oxygen demanding substances, and nutrients to the river. These pollutants may stimulate plant growth, and unpleasant conditions in recreation areas along the river and endanger the quality of water supplies which are diverted from the Ipswich. In addition, such a large quantity of effluent may increase virus concentrations in the river, causing a great threat to water supplies.

A decrease in treatment efficiency at these facilities may also endanger the quality of water supplies and bathing areas.

One beneficial effect of the advanced waste treatment facilities on the Ipswich would be the sewering of areas, North Reading and Middleton which are currently experiencing problems with subsurface disposal systems. However, actions not proposed in this concept, such as proper land use management, would probably make a greater improvement in Ipswich River quality.

The existing primary treatment facility in Ipswich would be upgraded to secondary treatment. This would cause a slight decrease in concentrations of hazardous substances in the Ipswich estuary.

All concepts propose secondary treatment facilities to serve the Towns of Lynn, Nahant and Saugus in a regional system; the South Essex Sewerage District; Gloucester, Rockport, and Essex. Establishment of secondary treatment facilities for these towns would have a great positive impact on water quality and the safety of recreation areas and shellfish harvesting areas. Presently all these towns with the exception of Essex, have municipal sewerage systems and are discharging raw sewage to the ocean. In addition, the Towns of Rockport and Essex have problems with malfunctioning subsurface disposal systems. Shellfish harvesting areas and bathing areas in Lynn Harbor, Beverly-Salem Harbor, Rockport Harbor, Gloucester Harbor and on the Essex River are closed due to pollution from these sources. Implementation of plans for secondary treatment for coastal towns will decrease bacteria counts in the water, making North Coastal waters safer for both contact and noncontact recreation, and shellfish harvesting.

Concept 5 proposes 3 rapid infiltration sites to handle the wastewater from the Ipswich, Hamilton, and Middleton facilities proposed in concepts 1-4. These sites total 190 acres in the towns of Boxford and Ipswich. Effluent application at these sites should not present health hazards (see page 126 and discussion of concept 5, page 170). In fact land application will remove more pathogens and nitrates than advanced waste treatment (see section B, page 122). Land application of wastewater from the town of Ipswich will eliminate potential threat of contamination of shellfish harvesting areas in the event of treatment facility breakdown. Buffer zones surrounding sites should prevent health hazards created by aerosol borne pathogens. Care must be taken, through proper management and monitoring, to: 1) prevent breakdown in the soils removal efficiency, and 2) prevent breeding of disease vectors and nuisances.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA WASTEWATER MANAGEMENT STUDY

Area: North Coastal - Ipswich River

Concept: 1,2,3,4,

PLAN ELEMENTS

1. AWT-Middleton
2. AWT-Hamilton
3. Change from primary to secondary treatment-Ipswich
4. Change from no treatment to secondary-coastal towns
5. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS (1.2.3.4.5.)		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1, 2	+L	Slight decrease in bacterial concentrations in some areas, as the effluent may contain less bacteria than the river water (Compare Table 27 to Table 31), and the effluent will constitute a major portion of the flow during periods of low flow.	Decreased hazard to recreation areas and water supplies, although it is not advisable to swim in or drink water that is largely AWT effluent (see below).	
1, 2	-L	Possible increase in virus concentrations by addition of such a large quantity of effluent, as chlorination does not remove all viruses.	Increased hazard to recreation areas and water supplies.	Employ a disinfection process that removes viruses.
1, 2	-L	Increase in nitrates due to nitrification, in combination with present levels of phosphorous, may promote algal blooms, leading stagnant odorous conditions.	Unpleasant conditions at recreation areas. Hazardous to Ipswich River as a water supply.	Denitrification to remove nitrates.
3	+L	Slight reduction in hazardous substances due to improved treatment.	Decreased hazard to recreation and shellfish areas.	
4	+L	Great decrease in concentrations of hazardous substances, especially bacteria, as wastewater is currently receiving no treatment, and there are no controls on the systems.	Decreased hazard to recreation and shellfish areas.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area North Coastal - Ipswich River (Cont'd)

Concept 1,2,3,4.

PLAN ELEMENTS

1. AWT-Middleton
2. AWT-Hamilton
3. Change from primary to secondary treatment-Ipswich
4. Change from no treatment to secondary - coastal towns
5. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.	2.	3.	4.	5.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
				●	+L	Elimination of pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas, shellfish areas, and water supplies.	
●	●	●	●		-S	Large treatment plants, especially in areas where there are presently none, and more extensive collection systems, cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas, shellfish areas, and water supplies.	
●	●	●	●	●	-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas, shellfish areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Ipswich River-South Coastal

Concept 5

PLAN ELEMENTS

1. RI Boxford and Ipswich for towns of Hamilton, Middleton, Topsfield, North Reading and Ipswich
2. Change from no treatment to secondary - coastal towns
3. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS	CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
+L	Elimination of pollution in areas with subsurface disposal problems.	Decreased hazard to recreation areas, and water supplies.	
+L	Provides greater removal of health hazards (pathogens and nitrates) than water-oriented treatment.	Decreased hazard to recreation areas and water supplies, and shellfish harvesting areas.	
-L	Breakdown in soil treatment efficiency may cause contamination of water supplies and recreation areas.	Increased hazard to recreation areas and water supplies	Proper management and monitoring of sites
-L	Possible contamination of air with aerosol borne pathogens.	Hazard to community health.	Establishment of adequate buffer zones
L	Possible breeding of disease vectors and nuisances.	Hazard to community health.	Proper management of sites and storage lagoons
+L	Great decrease in hazardous substances, especially bacteria, as wastewater is currently receiving no treatment, and there are no controls on the system.	Decreased hazard to recreation and shellfish areas.	
-S	Larger treatment plants and more extensive collection systems cause more pollution when malfunctioning	Temporary increased hazard to recreation areas, shellfish areas and water supplies	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA WASTEWATER MANAGEMENT STUDY

Area Ipswich River-South Coastal PLAN ELEMENTS

Concept 5 (Continued)

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS	CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
-S	Construction may temporarily degrade water quality	Temporary increased hazard to recreation areas, shellfish areas and water supplies	

g. The Sudbury, Assabet and Concord Watersheds (SUASCO)

All concepts propose the same plans for the Concord River Watershed. The existing secondary municipal wastewater treatment facility in Concord would be upgraded and expanded to a regional advanced waste treatment facility. The existing secondary treatment facility at Billerica would also be upgraded to advanced waste treatment. The regional facility at Concord would discharge 8.8 MGD (or 12.8 cfs) to the Concord River. This flow would be .6 times the river's 7 day-10 year low flow and .25 times the river's 7 day-2 year low flow at this point. The Billerica municipal facility would be expanded to discharge 6.4 MGD (or 7.8 cfs) to the Concord River. This facilities flow would constitute a much smaller portion of the river's flow than the flow from the Concord facility.

The advanced waste treatment facility at Concord would be beneficial as it would eliminate pollution from subsurface disposal systems in areas such as Acton. A higher level of treatment at these facilities would decrease concentrations of oxygen demanding wastes and bacteria in the effluent. However, the ratio of treatment facility discharge to river flow would be increased. Higher concentrations of nitrates in the effluent may be hazardous to the Billerica water supply, which is the Concord River below the proposed Concord treatment facility site. It is unlikely that higher concentrations of nitrates would produce eutrophication as the river is very fast moving, and nutrients are quickly flushed out. Adverse effects of nitrates may be mitigated by addition of denitrification to the treatment process. Also, the location of such a large treatment facility in Concord, above the Billerica water supply may be hazardous in the event of a breakdown in treatment efficiency.

In summary, plans for the Concord Watershed may be beneficial if care is taken to protect the Billerica water supply.

On the Sudbury River, concepts 2 and 4 propose 2 regional advanced waste treatment facilities in Framingham and Sudbury. The Framingham facility would discharge 19 MGD (or 29.4 cfs) to the Sudbury. This flow would be 24.5 times the 7 day 10 year low flow and almost 10 times the 7 day 2 year low flow of the river at this point. The Sudbury facility would discharge 5.9 MGD (or 8.4 cfs). This flow would be 2 times the 7 day-10 year low flow and .85 times the 7 day-2 year low flow of the Sudbury at this point.

Implementation of concepts 2 and 4 would eliminate pollution problems in areas with malfunctioning subsurface disposal systems, and allow a larger area of Framingham and Ashland to be sewered. Currently, new connections to the Framingham Interceptor, a part of the MDC sewer system, are prohibited, as the system is overloaded.

Addition of such a large quantity of advanced waste treatment effluent to the Sudbury would augment flow, recharge groundwater, and

decrease concentrations of certain pollutants, especially bacteria, in the river, causing less health hazards at recreation areas. However large quantities of nitrates from the effluent in combination with nutrients naturally present from the extensive marshland area that borders the river, may increase eutrophication, and unpleasant, odorous conditions. These nutrients would not be flushed out easily as the lower Sudbury is extremely slow moving. In addition, as chlorination does not remove all viruses; virus concentrations in the river may increase, posing a threat to recreation areas.

Also a decrease in treatment efficiency, especially at the Framingham facility, would be hazardous to the river system.

Because of nutrient problems in the river, such a large quantity of treatment facility effluent would not improve water quality. Addition of denitrification to the treatment process and substitution of ozonation for chlorination may mitigate adverse effects of these facilities on the Sudbury. Elimination of non-point sources and flow augmentation by other means would be a better solution to the Sudbury's water quality problems. Proper land use management in the towns of Wayland and Sudbury may eliminate the need for the Sudbury facility.

Concepts 1, 3 and 5 propose that the towns of Framingham, Ashland and Hopkinton (and Southborough under concept 1) discharge their wastes outside the watershed. This arrangement is basically a continuance of existing conditions and there would be only minor changes in water quality. The MDC Framingham Interceptor, which is currently overloaded, would have to be enlarged to accommodate larger flows from these towns. Concepts 1, 3, and 5 also propose an advanced waste treatment facility in Sudbury (as in concepts 2 and 4).

On the Assabet River, all concepts propose a regional advanced waste treatment facility in the western portion of Marlborough, discharging 9.3 MGD (or 14.4 cfs). This flow would be 9 times the 7 day-10 year low flow and 2.6 times the 7 day-2 year low flow of the Assabet at this point. All concepts also propose upgrading the Hudson secondary treatment facility to advanced waste treatment. Discharge from this facility would be 3.9 MGD (or 6.0 cfs). This flow would be 2.5 times the 7 day-2 year low flow of the river. After the year 2000 a regional facility would be built in Stow to service the communities of Hudson, Stow and Bolton.

The advanced waste treatment facility discharge in Hudson and western Marlborough would decrease concentrations of certain pollutants such as bacteria in the river, creating safer more pleasant recreation areas. Pollution from existing malfunctioning treatment plants and subsurface disposal systems would be eliminated. However concentrations of nitrates would increase in the river as the proposed treatment does not include denitrification. Nitrates in combination with nutrients from other sources may stimulate plant growth and unpleasant conditions. This adverse effect may be mitigated by addition of denitrification to the treatment process. The regional facility at Stow may not be needed by 2000 if the towns of Stow and Bolton limit development to areas that can accommodate subsurface disposal systems.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area SUASCO

Concept 1,3,5

PLAN ELEMENTS
1. AWT-Sudbury
2. Change from secondary to AWT-West Marlborough
3. Change from secondary - to AWT-Hudson (Stow (2000))
4. Change from secondary to AWT - Concord
5. Change from secondary to AWT - Billerica
6. Extension of collection systems

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.	2.	3.	4.	5.	6.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
●						+L	Decrease in bacterial concentrations because AWT effluent will constitute a large part of the flow during low flow, and AWT effluent will have lower bacterial concentrations than the Sudbury River (Compare Table 30 to Table 31).	Decreased hazard to recreation areas and water supplies. However, it would not be advisable to swim in water that is largely AWT effluent. (See below)	
●						-L	Possible increase in virus concentrations by adding such a large quantity of effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas, and water supplies.	More effective disinfection process such as ozonation.
●						-L	Increase in nitrates due to nitrification, in combination with present phosphorous levels may increase algal blooms, leading to depletion of oxygen, and stagnant, odorous conditions.	Unpleasant conditions at recreation areas.	Denitrification to remove nitrates.
	●	●	●	●		+L	Decrease in concentrations of hazardous substances, such as metals and bacteria, in the rivers, due to improved treatment.	Decreased hazard to recreation areas and water supplies.	
	●	●	●	●		-L	Increase in nitrates due to nitrification may, in combination with present phosphorous levels, cause algal blooms, leading to stagnant and odorous conditions.	Unpleasant conditions at recreation areas, and a hazard to water supplies.	Denitrification to remove nitrates.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area SUASCO

Concept 1,3,5 (cont'd)

PLAN ELEMENTS
1. AWT-Sudbury
2. Change from secondary to AWT-West Marlborough
3. Change from secondary to AWT - Hudson (Stow (2000))
4. Change from secondary to AWT - Concord
5. Change from secondary to AWT-Billerica
6. Extension of collection systems

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS (1.2.3.4.5.6.)		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
2, 3	+L	Elimination of presently malfunctioning treatment plants along the Assabet River	Decreased hazard to recreation areas.	
6	+L	Elimination of pollution in areas with malfunctioning sub-surface disposal sites.	Decreased hazard to recreation areas and water supplies.	
1, 2, 3, 4, 5, 6	-S	Large treatment plants especially in areas where there are presently none, and more extensive collection systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and water supplies.	
1, 2, 3, 4, 5, 6	-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: SUASCO

Concept: 2,4

PLAN ELEMENTS

1. AWT Framingham
2. AWT Sudbury
3. Change from secondary to AWT-West Marlborough
4. Change from secondary to AWT - Hudson - (Stow (2000))
5. Change from secondary to AWT - Concord
6. Change from secondary to AWT Billerica
7. Extension of collection systems

EXPLANATION OF IMPACTS

+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS 1.2.3.4.5.6.7.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
1, 2	+L	Decrease of bacterial concentrations at Framingham, and to a lesser extent at Sudbury, because AWT effluent will have lower bacterial concentrations than the Sudbury River (Compare Table 30 to Table 31), and the effluent will constitute a major portion of the flow during periods of low flow.	Decreased hazard to recreation areas and water supplies. However, it would not be advisable to swim in water that is largely AWT effluent (see below)	
1, 2	-L	Possible increase in virus concentrations by adding such a large quantity of AWT effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas and water supplies.	More effective disinfection process such as ozonation.
1, 2	-L	Increase in nitrates due to nitrification, in combination with present phosphorous levels may increase algal blooms leading to depletion of oxygen and stagnant odorous conditions.	Unpleasant conditions at recreation areas.	Denitrification to remove nitrates.
3, 4, 5, 6	+L	Decrease in concentrations of hazardous substances such as bacteria and metals due to improved treatment.	Decreased hazard to recreation areas and water supplies.	

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area SUASCO

Concept 2,4 (cont'd)

PLAN ELEMENTS
1. AWT Framingham
2. AWT Sudbury
3. Change from secondary to AWT-West Marlborough
4. Change from secondary to AWT-Hudson - (Stow (2000))
5. Change from secondary to AWT-Concord
6. Change from secondary to AWT- Billerica
7. Extension of collection systems

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
O Problematical impact

PLAN ELEMENTS 1.2.3.4.5.6.7.		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
3, 4	+L	Elimination of presently malfunctioning treatment plants along the Assabet River.	Decreased hazard to recreation areas.	
7	+L	Elimination of pollution in areas with malfunctioning subsurface disposal systems.	Decreased hazard to recreation areas and water supplies.	
1, 2, 3, 4, 5, 6, 7	-S	Large treatment plants, especially in areas where there are none, and more extensive collection systems cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and water supplies.	
1, 2, 3, 4, 5, 6, 7	-S	Construction may temporarily degrade water quality.	Temporary increased hazard to recreation areas and water supplies.	

h. <u>Areas Outside the Study Area - Southeastern Massachusetts</u>

Concept 5 proposes that wastewater treatment facility effluent from five regional satellite facilities proposed in concept 4 (Woburn, Medford, Watertown, Dedham and Canton) be transported to southeastern Massachusetts for land application by either spray irrigation or rapid infiltration. Secondary treatment, using some mode of the activated sludge process, would be employed at these facilities to treat a total of 177 MGD (by the year 2000). Effluent would then be transported in a southerly direction, via a mole tunnel, to equalizing storage lagoons in Canton. From Canton, the effluent would be pumped through force mains to storage lagoons in Freetown, Plymouth and Bourne. Storage lagoons at each of these sites would be large enough to store flows when rainy or cold weather interferes with land application. The storage capacity for spray irrigation sites would be 26 weeks, and for rapid infiltration sites would be 14 weeks. However it is believed that the mild climate of southern Massachusetts will enable land application by rapid infiltration to continue on a year round basis. Sludge from the 5 regional secondary facilities in the southeastern Massachusetts system would be thickened and stored at each plant, and conveyed via pipeline to the Dedham plant to be dewatered by vacuum filtration and incinerated in a multiple hearth incinerator. Resultant ash would be lagooned and then transported to sanitary landfills.

Land sites in southeastern Massachusetts suitable for effluent application are shown in Figure 26. Approximately 18,700 acres were found available and suitable for either spray irrigation or rapid infiltration.

In addition 3 rapid infiltration sites are proposed in the Ipswich River Watershed. Approximately 190 acres are available in Boxford and Ipswich to handle wastewater from the Ipswich, Hamilton and Middleton facilities proposed in concepts 1-4.

Sites chosen are sparsely populated forested areas. Soils on these sides will have proper permeability, infiltration capacity and depth to groundwater to prevent contamination of ground and surface waters. Effluent application rates of .5 to 4.0 inches per week for spray irrigation, and 4 to 12 inches per week for rapid infiltration, as well as application frequency, have been designed to prevent ponding and clogging of the soil, and to allow adequate removal of the effluents chemical and biological constituents by both crops and the soil system.

There will be sufficient removal of hygienic related effluent constituents by the soil system to prevent hazards to groundwater supplies (see section B(2) page 126).

Buffer zones of 1000 feet from human habitation, recreation areas and water supplies, and 200 feet from roads have been established at proposed spray irrigation sites. Such distances should be adequate in protecting the public from aerosol-borne pathogens (see page A-11). Slope of the land at all proposed sites is less than 10 to 15 percent to prevent surface runoff and contamination of surface water. Care must be taken to properly maintain and monitor these systems as a breakdown in the soils treatment efficiency could lead to contamination of water supplies and recreation areas. Precautions must also be taken to prevent breeding of disease vectors and nuisances, such as mosquitoes, at both application and lagoon sites. Two species of mosquitoes in southeastern Massachusetts are known vectors of eastern encephalitis (see page A-13).

Specific site related impacts are:

1. Possible contamination of Copicut Reservoir, the Fall Water Supply.

2. Possible contamination of cranberry bogs in Freetown, Carver, Wareham and Sandwich.

3. Possible contamination of water supply wells in Bourne.

4. Possible creation of health hazards to those using Myles Standish Reservation in Plymouth, and the Freetown-Fall River State Forest.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area: Southeastern Massachusetts

Concept: 5

PLAN ELEMENTS
1. Land application - Taunton River Watershed
2. *Land application - South Coastal, Buzzards Bay*
3. Land application - Cape Cod

EXPLANATION OF IMPACTS
- +L Beneficial impact-long term
- -L Adverse impact-long term
- +S Beneficial impact-short term
- -S Adverse impact-short term
- 0 Problematical impact

PLAN ELEMENTS	CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
+L	Reduces treatment facility flow and potential threat of pollution to Boston Harbor.	Decreased Hazard to Harbor recreation and shellfish areas.	
+L	Provides better removal of pathogens and nitrates than advanced waste treatment.	Decreased hazard to recreation areas and water supplies in eastern Massachusetts.	
-L	Possible contamination of air by aerosol-borne pathogens.	Health hazard to those using Freetown-Fall River State Forest, Watuppa Reservation, Myles Standish Reservation and other recreation areas.	Establish adequate buffer zones around application sites.
-L	Possible breeding of vectors of disease and nuisances at application and lagoon sites.	Health hazard to those living in or using areas around land application sites.	Proper maintenance of sites and lagoons.
-L	Breakdown in soils treatment efficiency may contaminate recreational waters and water supplies	Increased hazard to recreation areas and water supplies, especially Copicut Reservoir, Fall Rivers water supply, and water supply wells in Bourne.	Proper maintenance and monitoring of sites.
-L	Possible contamination of cranberry bogs	Increased health hazards	Establish adequate buffer zones around application sites.

ASSESSMENT OF HYGIENIC IMPACTS

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

Area Southeastern Massachusetts PLAN ELEMENTS

Concept 5 (Continued)

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

PLAN ELEMENTS		CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
	-S	Long transmission lines may cause large amounts of pollution when malfunctioning.	Temporary increased hazard to water supplies and recreation areas in Southeastern Massachusetts.	
	-S	Construction may degrade water quality.	Temporary increased hazard to water supplies and recreaction areas.	

3. Impact Assessment of Concept 6

The technical subcommittee of the Boston Harbor-Eastern Massachusetts Metropolitan Area Wastewater Management Study, after evaluation and analysis of impacts of the five alternative plans for wastewater management, as well as consideration of opinions voiced at public meetints, selected a recommended plan for the study area. This recommended alternative plan, concept 6, is actually a hybrid concept. Actions proposed by Concept 6 and probable impacts of these actions are discussed below, by watershed.

a. Boston Harbor

Concept 6 proposes maintenance of the Deer Island facility's current service area, reduction of the Nut Island facility's service area, and regional plants to serve outlying communities. Both Deer and Nut Island would be upgraded to secondary treatment. These actions would have little impact on water quality in the Harbor, as water quality here is largely related to pollution from other sources.

b. Mystic River Watershed

A 2 MGD advanced waste treatment facility is proposed on the Aberjona River. Flow from this facility would be 8 times the river's 7 day-10 year low flow and .4 times the river's average flow for the months of July through October (stream flow comparisons are shown in Table 33). Addition of effluent to the Aberjona will augment flow in the river, and mitigate stagnant, odorous conditions in the summer months by flushing out pools of highly polluted water that are created along the river during summer low flow conditions. Such a large quantity of effluent in relation to stream flow would dilute concentrations of bacteria and oxygen demanding wastes. Bacterial reduction would be beneficial to recreation areas, in particular, the Upper Mystic Lake.

However, if the proposed level of treatment is employed at this facility, concentrations of nitrates and phosphorous may increase in the Aberjona and Upper Mystic Lakes, stimulating eutrophic conditions which already exist during summer. In addition, a chlorinated effluent may still contain virus concentrations as high as 150 PFU/1 . If such a large quantity of effluent is added to the stream virus concentrations may increase, posing a public health threat to recreation areas. Breakdown in treatment efficiency would intensify these adverse impacts. Adverse effects may be mitigated by addition of denitrification to the proposed treatment process, and employment of a more effective method of disinfection, such as ozonation. Flow augmentation by other means may cause greater water quality improvement of the Aberjona and Mystic Lakes.

TABLE 34

STREAM FLOW COMPARISON - Concept 6

Recommended Advanced Wastewater Treatment Facility Location	Average Discharge (mgd) (year 2000)	Receiving Stream	Upstream Effluent Discharge (mgd)	10 yr - 7 day Low Flow (mgd)	July through October Average Flow (mgd)	Annual Average Flow (mgd)	100 yr Flood Flow (mgd)
Woburn	2	Aberjona River	0	0.25	5	18	790
Canton	30	Neponset River	0	7	40	95	1300
Wellesley	30	Charles River	16	7	80	195	2650

mgd - million gallons per day

c. Neponset River Watershed

An advanced waste treatment facility is proposed on the Neponset River, adjacent to the Route 128 interchange in Canton. This facility would discharge 30 MGD, and serve the towns of Canton, Walpole, Norwood, Sharon and Stoughton. Effluent discharge from this facility would be 4.3 times the 7 day-10 year low flow and .75 times the average flow in the river at this point for the months of July through October. Discharge of advanced waste treatment effluent to the Neponset would increase flow and concentrations of coliform bacteria in river water, as maximum effluent concentrations (1000/100 ml) would be less than bacteria concentrations in this stretch of the river (up to 15,000/100 ml).

However concentrations of ammonia and nutrients in the river at this point may be less than such concentrations in the treatment facility effluent. Discharge of an effluent of the quality proposed by the MDC would have an adverse effect on the Neponset, as increased nutrients, especially a great increase in nitrates, would promote algal blooms and unpleasant conditions. High nitrate levels may also endanger the quality of present and potential groundwater supplies in Fowl Meadow Marsh, as the aquifer underlying the marsh is hydraulically connected to the river, and a lowering of the water table can cause pollutants in the river to percolate into groundwater.

In addition, since the proposed treatment includes chlorination as a mode of disinfection, not all viruses would be removed from the effluent. Increased virus concentrations in the river could lead to viral contamination of groundwater supplies in Fowl Meadow Marsh. Breakdown in treatment efficiency at the facility would intensify health hazards in water supplies.

Due to these adverse impacts a wastewater treatment facility in Canton cannot be recommended. These impacts could be mitigated by addition of denitrification to the treatment process, and use of a more effective disinfection process such as ozonation.

d. The Charles River Watershed

Concept 6 proposes an advanced waste treatment facility on the Charles River to serve the towns of Wellesley, Natick, Framingham, Ashland, Hopkinton, Southborough and parts of Dover and Sherborn if needed. Flow from this facility would be 30 MGD, 4.3 times the 7 day-10 year low flow and approximately .4 times the average flow for the months of July through October. Addition of such a large quantity of effluent to the river would increase flow. This may be quite an important beneficial impact to the Charles at this point, as a study made by M. H. Frimpter, (48) of the U.S. Geological Survey, shows that flow in this stretch of the Charles may decrease to zero during 55 days of the year by the year 2000 due to an increased demand on water supplies along the river, and continuance of the practice of discharging wastewater to the Harbor. Discharge of advanced waste treatment effluent would also decrease bacterial concentrations in the river, as such concentrations are presently much higher than such concentrations in the effluent.

However concentrations of nutrients would increase, as concentrations of nitrates and phosphorous would be higher in the effluent than those in the river. Higher nutrient levels may promote excessive plant and algal growth in this slow moving portion of the river, causing unpleasant conditions for those living along the river and those using it for recreation.

Also virus concentrations in the river may increase, as chlorination of effluents does not remove all viruses. This would be a health hazard to groundwater supplies hydraulically connected to the River, as well as recreation areas.

Adverse effects would be mitigated by addition of denitrification to the treatment process, and use of a more effective means of disinfection. Concept 6 also proposes advanced waste treatment facilities in Milford, Medway and Medfield. Impacts of these facilities would be the same as those for concepts 1, 2 and 4.

TABLE 35

SUMMARY OF HYGIENIC IMPACTS - CONCEPT 6

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

	CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
	MYSTIC RIVER WATERSHED		
+L	Increased flow will improve stagnant conditions, and flush out pollutants in summer months.	More pleasant conditions at recreation areas.	
+L	Decrease in bacterial concentrations, as treatment plant effluent will constitute a major portion of river flow during periods of low flow. (Compare bacterial concentrations in the Aberjona, Table 16 to bacterial concentrations in AWT effluent, Table 31).	Decreased hazard to recreation areas; however, it would not be advisable to swim in water that is largely treatment plant effluent (see below).	
-L	Possible increase in virus concentrations by adding such a large quantity of treatment plant effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas, especially the Upper Mystic Lake.	Employ disinfection process that removes viruses.
0	Decrease in oxygen demand in Aberjona due to discharge of such a large quantity of effluent with lower concentrations of ammonia and BOD than some portions of the River (Compare Table 16 to Table 31), thus promoting less stagnant and odorous conditions. However increase in nitrates due to nitrification, in combination with present phosphorous levels, may cause algal blooms, and promote stagnant conditions.	Unknown impact depending on whether concentrations of nitrates and phosphates will increase or decrease algal blooms.	Denitrification to remove nitrates.
-S	Breakdown in treatment efficiency may cause very high levels of nutrients and pathogenic organisms in the Aberjona.	Increased hazard to recreation areas, especially Upper Mystic Lake.	

TABLE 35 (Continued)

SUMMARY OF HYGIENIC IMPACTS - CONCEPT 6

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

	CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
	NEPONSET RIVER WATERSHED		
+L	Decrease in bacterial concentrations in the water as AWT effluent will constitute a major portion of the flow at these sites during periods of low flow. (Compare water quality of the Neponset, Table 19 to quality of AWT effluent, Table 31).	Decreased hazard to recreation areas and water supplies in Fowl Meadow Marsh.	
-L	Possible increase in virus concentrations by adding such a large quantity of effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas and groundwater supplies in Fowl Meadow Marsh.	Employ a more effective disinfection process, such as ozonation.
-L	Increase in nitrates due to nitrification, in combination with present phosphorous levels may increase algal blooms, leading to depletion of oxygen, and stagnant, odorous conditions.	Unpleasant conditions at recreation areas.	Denitrification to remove nitrates.
-L	Increase in nitrates may cause high nitrate levels in groundwater in Fowl Meadow.	Increased hazard to water supplies.	Denitrification to remove nitrates.
-S	Locating treatment plants where there are presently none can cause short term degradation of water quality when a plant is malfunctioning.	Temporary increased hazard to recreation areas and water supplies.	

TABLE 35 (Continued)

SUMMARY OF HYGIENIC IMPACTS - CONCEPT 6

BOSTON HARBOR-EASTERN MASSACHUSETTS METROPOLITAN AREA
WASTEWATER MANAGEMENT STUDY

EXPLANATION OF IMPACTS
+L Beneficial impact-long term
-L Adverse impact-long term
+S Beneficial impact-short term
-S Adverse impact-short term
0 Problematical impact

	CHANGE IN ENVIRONMENTAL QUALITY	IMPACT	MITIGATION MEASURES
	CHARLES RIVER WATERSHED		
+L	Decrease in bacterial concentrations, as AWT effluent will constitute a large portion of the flow at both sites during periods of low flow. (Compare bacterial concentrations in Charles, Table 21, to bacterial concentrations in AWT effluent, Table 31).	Decreased hazards to recreation areas and groundwater supplies along the river.	
+L	Augmentation of flow will improve stagnant doncitions and provide more water to towns whose water supplies are hydraulically connected to the river.	Decreased hazard to water supplies.	
-L	Possible increase in virus concentrations by adding such a large quantity of effluent to the river, as chlorination does not remove all viruses.	Increased hazard to recreation areas and water supplies.	More effective disinfection process, such as ozonation.
-L	Increase in concentrations of nitrates due to nitrification of effluent may in combination with present phosphorous levels promote algal blooms in many areas, leading to stagnant odorous conditions.	Unpleasant conditions at recreation areas.	Denitrification to remove nitrates.
-L	Increase in concentrations of nitrates may increase nitrates in groundwater supplies along the river.	Increased hazard to water supplies.	Denitrification to remove nitrates.
-S	Large treatment plants, especially in areas where there are presently none, can cause more pollution when malfunctioning.	Temporary increased hazard to recreation areas and water supplies.	

IV. RECOMMENDATIONS AND CONCLUSIONS

Concept 1 is preferred from a hygienic standpoint, as it would cause fewer adverse impacts than other proposed concept.

Unlike the decentralized concepts 2 and 4, concept 1 does not propose location of advanced treatment facilities on rivers tributary to Boston Harbor, and therefore does not have the potential to contaminate and degrade recreation waters and water supplies in and on these rivers. Advanced treatment effluent of the quality proposed by the Study (See Figure 28) may cause high nitrate concentrations, leading to excessive algal growth, and hazardous virus concentrations in receiving waters, thus making decentralized concepts less desirable. Addition of denitrification to remove nitrates from facility effluent and replacement of chlorination with ozonation, as a disinfection process, would mitigate adverse effects of concepts 2 and 4.

The land application system proposed by concept 5 is also less desirable than concept 1 as it may cause potential adverse consequences of: contamination of ground and surface water supplies in the event of system malfunction, contamination of air by aerosol borne pathogens, and breeding of vectors of disease.

Concept 3, which proposes maximum centralization of the Metropolitan Sewerage District, is the least desirable concept. Discharging the entire wastewater flow from communities in the Charles River Watershed to Boston Harbor could lead to severe low flow conditions on the Charles, and lower the yield of water supply wells hydraulically connected to the Charles.

The Study's Recommended Concept (concept 6) is rated midway between concept 1 and the decentralized concepts 2 and 4. This concept may potentially cause adverse effects of excessive nitrate and virus concentrations in rivers receiving treatment facility discharge; however it proposes fewer inland treatment facilities than concepts 2 and 4. Also, the proposed Wellesley area treatment facility would have a beneficial impact on the Charles in terms of flow augmentation.

To ensure hygienic acceptability of the Recommended Concept, further study must be performed on the effects of advanced treatment facility discharge to the Charles and Neponset Rivers, and the impacts of such a discharge on water supply wells located along these rivers. Also, addition of denitrification to the recommended treatment processes, and replacement of chlorination by ozonation must also be considered to mitigate adverse effects.

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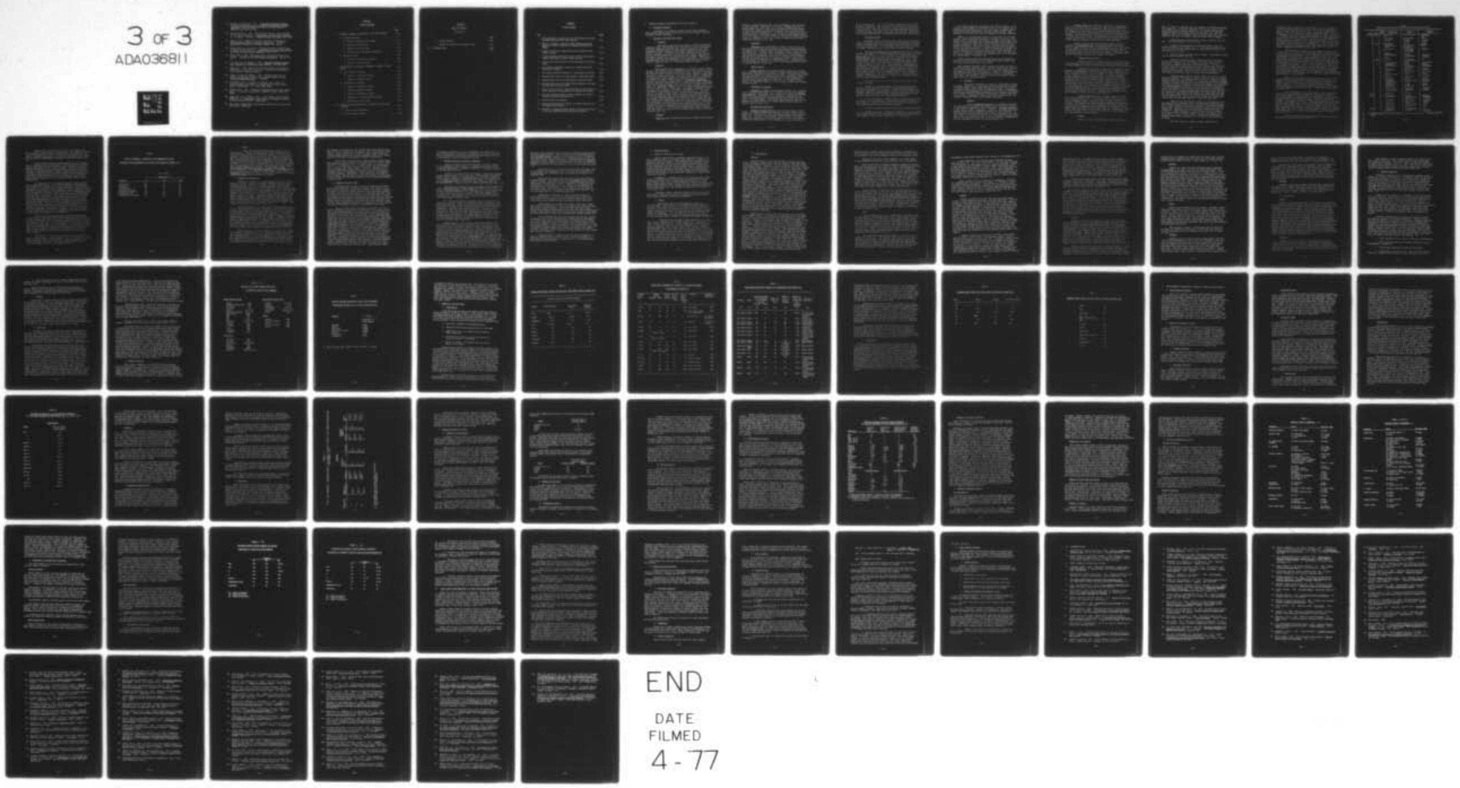

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ADDENDUM

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I. POTENTIAL HAZARDS OF WASTEWATER TO THE PUBLIC HEALTH

A. Biological Hazards

Wastewater is a potential carrier of many human pathogens. These disease causing agents can be divided into four groups: bacteria, parasites, viruses, and fungi.

1. Hazards in Effluents and Sludge

a. Bacteria

Bacteria are unicellular plants some of which are potential pathogens to man. Many bacteria have the ability to live in the outside world, and synthesize their own food; however, others must take their nourishment from the bodies of living hosts, sometimes at the cost of injury to the host. As opposed to viruses, discussed later in this section, bacteria usually live outside the host's cells. Many bacteria are found in the feces of man, and therefore are potential hazards in wastewater, sludges, and contaminated lakes and streams. A few of these known waterborne bacterial pathogens will be mentioned here, although numerous others may exist in a contaminated water environment.

Salmonella

Numerous serotypes of Salmonella are pathogenic to both animals and man. The commonest clinical manifestations of this disease are acute gastroenteritis with diarrhea and abdominal pains; although, occasionally the clinical course is that of enteric (intestinal) disease or septicemia (infection of the blood stream). The most frequent mode of transmission is through food or water supplies contaminated by infected feces of man and animals. In 1966, a severe epidemic of Salmonella typhimurium diarrhea, affecting over 15,000 people occurred in Riverside, California where the source of contamination was an unchlorinated public groundwater supply (1). Salmonella typhi, the causative agent of typhoid fever, is infectious only to man. Typhoid fever is a serious disease characterized by fever, loss of appetite, slow pulse, involvement of lymphoid tissue, enlargement of the spleen, and usually, constipation (1). Its occurrence in the United States is rare. However, the largest waterborne outbreak of typhoid in this country since the 1930's occurred in early 1973 at the South Dade Labor Camp in Homestead, Florida, affecting 213 of the camp's 1900 inhabitants. The camp was served by a well that had been intermittently contaminated over the years, and, although the water was chlorinated, controls were found to be unsatisfactory. "Operating records revealed that unchlorinated water was distributed prior to the outbreak, and fecal contamination was documented in the wells and distribution system" (2). Six hundred and twenty eight cases of typhoid fever were reported to the U.S. Public Health Service Center for Disease Control in 1973 (3).

Shigella

Shigellas cause intestinal disturbances ranging from very mild

diarrhea to severe dysentary with intense inflammation and ulceration of the large bowel. Two-thirds of the cases of Shigellosis occur in children under 10 years of age; and in the United States the disease is moderately endemic in lower socio-economic areas, on Indian reservations, and in institutions (1). The disease is transmitted by person-to-person contact, contaminated food, and poor quality drinking water. Craun and McCabe (2). in their "Summary of Water-borne-Disease Outbreaks in the U.S. during 1971 and 1972," reported 6 water-borne outbreaks of Shigellosis resulting in 617 cases.

Leptospira

Leptospira are coiled-shaped, actively motile bacteria that gain access to the blood stream through abrasions and mucous membranes (4) causing fever, headache, chills, vomiting, muscular aches, and conjunctivitis (1). In severe cases, the kidneys, liver, and central nervous system may be affected. Most outbreaks occur among swimmers exposed to water contaminated by the urine of domestic or wild animals; although the disease may also be transmitted by direct contact with infected animals or ingestion of contaminated water. Thirty-nine cases of this disease were reported to the U.S. Public Health Service Center for Disease Control in 1973 (3).

Vibrio cholera

Vibrio cholera is the causative agent of cholera, a serious acute intestinal disease characterized by sudden onset, watery diarrhea, dehydration, acidosis, and circulatory collapse. Untreated case fatality rate may exceed 50%. The disease is most often transmitted by water contaminated with feces of infected persons, or food contaminated by polluted water, soiled hands, or flies (1). In the 19th century, cholera was widespread; however, in this century, epidemics are largely confined to Asia.

Pastuerella tularensis

Tularemia, a disease characterized by chills, fever, prostration, and swollen lymph nodes (1), is caused by the bacteria, Pastuerella tularensis. The disease often infects wild animals, and the most common modes of transmission are the handling of contaminated wild animals and drinking water contaminated with urine, feces, and dead bodies of infected animals. One hundred and fifty-seven cases of this disease were reported to the U.S. Public Health Service Center for Disease Control in 1973 (3).

Mycobacteria tuberculosis

Mycobacterium tuberculosis is the causative agent of tuberculosis, a pulmonary disease with symptoms of cough, fatigue, fever, weight loss, and chest pain, which are sometimes absent until advanced stages (1). Incidence of the disease is decreasing in the United States; the incidence of new cases was 30,937 in 1973. It is usually transmitted through contact with the sputum of an infected person or

by the airborne route. The first documented waterborne case of human infection, reported in 1947, involved three children who fell into a heavily polluted river, 600 feet below a sewage discharge coming from a sanitarium (4). Since then, other cases involving near drowning of children in sewage contaminated water have been reported. Skin infections caused by mycobacteria in bathing waters have also been reported.

Coliform bacteria

Standard Methods (5) defines the coliform group as including "all of the aerobic and facultative anaerobic gram-negative, non-spore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C." All organisms in this group may be found in raw sewage, although many may also be found in natural habitats.

The sub-group *Escherichia coli* has been found to be a characteristic inhabitant of the intestines of warm blooded animals, and therefore a better indicator of fecal pollution (6). Various serotypes of *Escherichia coli* can cause gastroenteritis, characterized by profuse watery diarrhea, nausea, prostration, and dehydration (1). This disease agent commonly causes diarrhea in infants and children under 2 years of age, and is also found to be the cause of diarrhea and urinary infections in adults (4). Enteropathogenic *Escherichia coli* are present in streams and lakes polluted with feces of warm blooded animals, and are therefore threats to people using these waters as water supplies or bathing areas. *Escherichia coli* has a shorter survival time than some coliform sub-groups, and it is less resistant to chlorine disinfection. For this reason the total coliform group is preferred over *Escherichia coli* as an indicator of pollution, and ineffective water treatment methods.

Fair and Geyer (7) list the following criteria for a good indicator organism.

1. "It must be a reliable measure of the potential presence of specific contaminating organisms both in natural waters and waters that have been subjected to treatment. To meet this requirement, the indicator organism or organisms must react to the natural aquatic environment and to treatment processes, including disinfection, in the same way, relatively, as do the contaminating organisms."

2. "It must be present in numbers that are relatively much larger than those of the contaminating organism whose potential presence it is to indicate. Otherwise the presence of the contaminating organism itself would serve a more directly useful purpose."

3. "It must be readily identified by relatively simple procedures."

4. "It must lend itself to numerical evaluation as well as qualitative identification, since a knowledge of the degree of contamination is an essential interest and responsibility of the engineer."

The coliform group does meet most of the criteria listed. It is present in large numbers in contaminated water; it can readily and inexpensively be identified; and it does lend itself to numeric evaluation by statistical estimate with the Most Probable Number (MPN) technique, or by direct count with the Membrane Filter (MF) technique.

However, it is questionable whether it meets the first of these criteria. Many studies have shown that coliforms do not react to the natural aquatic environment and treatment processes in the same way as viruses. It has been found that viruses generally survive longer, and are more resistant to many forms of water treatment that kill nearly 100% of the baçteria. The total coliform count has particular questionable value for application to renovated wastewater for potable use as it cannot indicate potential hazards of all disease organisms. It is also of limited use in testing bathing water, since more than one half of all illnesses contracted from swimming water is not intestinal, but nasopharyngeal, in character (8).

Simpler and more effective techniques need to be developed for detection of other disease entities, especially viruses, before they can become accepted indicators of pollution.

Many organisms mentioned in this section on bacteria are able to survive many days in polluted water. The best conditions for long survival are low temperature, low population of bacterial competitors, and quantities of nutrient rich waste (4). Under the right conditions, these bacteria can be carried many miles in a river to contaminate other areas. Many species of fish can also act as carriers of pathogenic bacteria to unpolluted waters.

b. Parasites

Parasitism is defined as a symbiotic relationship in which one animal, the host, is to some degree injured through the activities of another animal. These animal parasites of man may be unicellular (protozoa) or multicellular (such as flatworms, flukes, or roundworms). Protozoa can be distinguished from bacteria, which are also unicellular, due to their larger size (between 10-200 microns) and their more intricate structure. Parasites of man are also found in human feces, and therefore a potential threat in wastewater and sludge.

Protozoa

Cysts of Entamoeba histolytica, a pathogenic protozoan, are often found in wastewater and sludge, as they are quite resistant to many adverse conditions in their environment. Entamoeba histolytica is the causative agent of amebiasis, a disease of the large intestine. Symptoms range from mild abdominal discomfort to acute dysentary. If not treated, the infection may spread to produce abscesses of the liver, lung, brain, or ulceration of the skin (1). The disease is most prevalent in rural and low income areas. Its usual mode of transmission is by water contaminated by feces of infected persons (1).

Giardia lamblia is a pathogenic protozoan that invades the small bowel causing symptoms ranging from mild diarrhea and abdominal pains to steatorrhea (fat maladsorption), anemia, and fatigue (1). The disease is more prevalent in the areas of poor sanitation, where it is transmitted by water contaminated by feces containing cysts of the parasite. In 1974 there was an outbreak of 67 cases of this disease in a small town in Vermont due to contamination of a water supply with a septic tank overflow. Craun and McCabe (2) reported four outbreaks of this disease resulting in 409 cases in the years 1971-1972.

Another extremely dangerous protozoan parasite found in wastewater is Naegleria gruberi, and amoeboflagellate that is the causative agent of primary amebic meningoencephalitis (1). Most causes of this disease occur in the summer months when persons who swim in contaminated water acquire the infection through the nasal cavity (9). The clinical course of the disease is quite dramatic, leading to neurological involvement and often death within 3 to 6 days.

Multicellular parasites

Parasitic worms are a special threat to sewage treatment plant operators, farm laborers involved in irrigation agriculture, and to people swimming in lakes polluted by sewage or runoff from feed-lots (4).

Ingestion of the larvae of beef or pork tapeworm, Taenia saginata or Taenia solium through eating inadequately cooked beef or pork can cause taeniasis. The larval stages of these parasites attach to the intestinal mucosa in man and develop into adult tapeworms, causing abdominal pain and indigestion (9). The animals themselves become infected by ingesting eggs attached to plants grown in spray irrigated fields or on land disposal sites. Humans may also become infected with the eggs of these tapeworms by ingestion of contaminated food and water (1). These eggs hatch in the small intestine of man and the larval forms, or cysticerci migrate through the body and develop in the subcutaneous tissues and striated muscles. Blindness or motor and sensory disturbances may result when the larvae develop in the eyes or central nervous system (1). Incidence of this disease in the United States is usually less than one percent (3).

Ascaris lumbricoides is a roundworm that can infect the large intestine of man. It is usually found in tropical and temperate climates in areas of poor sanitation (1), where infection is acquired through ingestion of food or water contaminated with eggs of the worm. The ingested eggs undergo migration through the body before returning to the stomach to grow to adulthood (9). Small numbers of worms may cause no symptoms; large numbers may cause digestive disturbances, pain, vomitting, and bowel obstruction due to migration of the worms to appendix, liver, or peritoneal cavity (1). These worms may be a great hazard in sludge disposal.

c. Viruses

Viruses are the smallest pathogenic organisms known to

man. In contrast to bacteria, they are incapable of multiplying outside the living cell. It has been hypothesized that viruses have evolved from bacteria through genetic mutation to the "summit of parasitism," losing all powers to synthesize their own nutrients (10). They are capable of life only if furnished with the enzymic mechanisms, nutritive resources, and source of energy of some particular plant or animal.

Viruses have no cell structure, nucleus, cytoplasm, nor cell wall. They are composed of two parts (10):

1. A singular linear molecule of RNA (acids found in the cell nucleus, carriers of the genetic code). This molecule constitutes the core, and is the active, disease specific, host specific, genetic, infective part of the virus.

2. A protein sheath coating, called a capsid -- the purpose of this coat is solely to protect the core.

Viruses are extremely small, ranging from 30 to 300 millimicrons (one micron is only 1/25,000th of an inch), and can exist in many forms of symmetry, the most common being cubic. The core of the virus can easily become separated from its protein coat, and thus be made vulnerable to RNA digesting enzymes. However, when the virus loses its coat, it loses only its infectivity, not its genetic and reproductive properties. If the virus core is not destroyed, it may also regain its coat and assume its former infective properties.

The mechanism by which a virus is taken into the cell is still relatively unknown. Some have been found to enter the cell by a process known as pinocytosis, or engulfment by the cell (10). Another mechanism by which a virus may enter the host cell is demonstrated by bacteriophage (bacterial viruses). The phage particle comes in contact with a bacterial cell that has receptor sites with a certain physiochemical specificity. If the physiochemical structure of the virus particle corresponds to that of the receptor site of the bacterial cell, the virus is adsorbed on the cell wall. The bacteriophage makes an opening in the cell wall and releases its RNA inside the bacterial cell. Once inside the cell, the viral core breaks down the cell DNA and synthesizes the viral RNA from its genetic code. Thus, new infective viruses are formed which finally burst the cell and circulate to infect new cells (10).

There are over 100 different species of viruses known to infect humans by the waterborne route. This grouping of human viruses, which consists mainly of those which multiply in the gastrointestinal tract of man, includes the infectious hepatitis virus, entero-viruses (poliovirus, conxsackie virus, and echovirus), adenoviruses and reoviruses (4). Large quantities of these viruses are found in human feces and therefore in sewage, sewage effluents, and polluted rivers and streams. Viruses of plant, animal, and bacterial origin also abound in these waters, although little is known of their importance to humans.

The viral content of sewage is small compared to its

bacterial content. Shuval, in a broad study of viruses in sewage, recovered from five plaque forming units (PFU) to over 11,000 PFU per liter in sewage from the same city (11). (A plaque forming unit is a measure of one virus particle growing on laboratory media). Studies by Geldeich et al calculate the coliform density in human feces to be 13 x 10^6/gram (12) other studies have estimated the viral concentration of feces to be 200 virus unit/gram. This gives a virus to coliform density ratio of 15 viruses to every million coliforms. Shuval's study in Israel found the ratio to be 1:1,000,000 (10). However, Berg estimates that, due to imperfection of techniques for viral detection, the amounts of viruses in sewage and river water exceeds by at least two orders of magnitude the amount detected (13).

The importance of viruses does not reside in numbers, but in infectivity. It is felt that the smallest quantities of virus that can be detected in susceptible cells in laboratory cultures (one plaque-forming unit) are sufficient to produce infection in man (14). The total effect of viruses are not easily detected as many times small amounts produce infection but not disease. Infection occurs when the virus enters the cell and multiplies. Overt disease occurs when there is sufficient cell damage to cause systemic malfunction (malfunction of a specific body system). Danger lies in the fact that an infected person with no disease symptoms can excrete large numbers of viruses, thus causing his contacts to become infected or to get the disease. The medical field estimates that for each person who visits a physician with identifiable viral symptoms, 100 to 1,000 other people are infected, posing threats as carriers (15).

Many viral disease outbreaks are accounted for by the term gastroenteritis. Gastroenteritis (inflammation of the stomach) is a symptom of a disease that may be caused by bacteria, chemicals, or viruses. Since it is not required that this disease be reported to health authorities, it can only be estimated that the number of viral cases occurring per year is in the 100s of 1,000s, many of them being waterborne (15).

Virus transmission by the water route is best demonstrated by the virus causing infectious hepatitis, a disease of the liver. From 1895 to 1964 there were at least 50 outbreaks of infectious hepatitis attributable to contaminated water. The largest waterborne epidemic of this disease occurred in Delhi, India during the years 1955 and 1956. The epidemic, caused by a contaminated municipal water supply, involved over 27,000 clinical cases, and an estimated ten times this number in subclinical cases (4). Craun and McCabe reported 11 waterborne outbreaks of the disease in the United States during 1971 and 1972, causing 266 cases (2). A total of 51,523 cases of infectious hepatitis were reported to the U.S. Public Health Service Center for Disease Control in 1973 (3).

A list of potential waterborne viruses and their associated diseases and symptoms are given in Table 1.

TABLE I

The Huamn Enteric Viruses That Can Be Waterborne and Known Diseases Associated With These Viruses

Group	Subgroup	No. of Types or Subtypes	Disease Entities Associated With These Viruses	Pathologic Changes in Patients	Organs Where Virus Multiplies
Enterovirus	Poliovirus	3	Muscular paralysis	Destruction of motor neurons	Intestinal mucosa, spinal cord, brain stem
			Aseptic meningitis	Inflammation of meninges from virus	Meninges
			Febrile episode	Viremia and viral multiplication	Intestinal mucosa and lymph
	Echo virus	34	Aseptic meningitis	Same as above	Same as above
			Muscular paralysis	Same as above	Same as above
			Guillain-Barre's Syndrome*	Destruction of motor neurons	Spinal cord
			Exanthem	Dilation and rupture of blood vessels	Skin
			Respiratory diseases	Viral invasion of parenchymatous of respiratory tracts and secondary inflammatory responses	Respiratory tracts and lungs
			Diarrhea		
			Epidemic myalgia	Not well known	
			Pericarditis and myocarditis	Viral invasion of cells with secondary responses	Pericardial and myocardial tissue
			Hepatitis	Same as above	Liver parenchyma
	Coxsackie virus	>24	Herpangina†	Viral invasion of mucosa with secondary inflammatory responses	Mouth
			Acute lymphatic pharyngitis	Same as above	Lymph nodes and pharynx
	A		Aseptic meningitis	Same as above	Same as above
			Muscular paralysis	Same as above	Same as above
			Hand-foot-mouth disease‡	Viral invasion of cells of skin of hands and feet and mucosa of mouth	Skin of hands and feet and much of mouth
			Respiratory disease	Same as above	Same as above
			Infantile diarrhea	Viral invasion of cells of mucosa	Intestinal mucosa
			Hepatitis	Viral invasion of liver cells	Parenchyma cells of liver
			Pericarditis and myocarditis	Same as above	Same as above
	B	6	Pleurodynia§	Viral invasion of muscle cells	Intercostal muscles
			Aseptic meningitis	Same as above	Same as above
			Muscular paralysis	Same as above	Same as above
			Meningoencephalitis	Viral invasional invasion of cells	Meninges and brains
			Pericarditis, endocarditis, myocarditis	Same as above	Same as above
			Respiratory diseases	Same as above	Same as above
			Hepatitis or rash	Same as above	Same as above
			Spontaneous abortion	Viral invasion of vascular cells (?)	Placenta
			Insuin-dependent iabetes	Viral invasion of insulin producing cells	Langerhans' cells of pancreases
			Congenital heart anomalies	Viral invasion of muscle cells	Developing heart
Reo virus		6	Not well known	Not well known	
Adenovirus		31	Respiratory diseases	Same as above	Same as above
			Acute conjunctivitis	Viral invasion of cells and secondary inflammatory responses	Conjunctival cells and blood vessels
			Acute appendicitis	Viral invasion of mucosa cells	Appendix and lymph nodes
			Intussusception	Viral invasion of lymph nodes (?)	Intestinal lymph nodes (?)
			Sub acute thyroiditis	Viral invasion of parenchyma cells	Thyroid
			Sarcoma in hamsters	Transformation of cells	Muscle cells
Hepatitis		>2	Infectious hepatitis	Invasion of parenchyma cells	Liver
			Serum hepatitis	Invasion of parenchyma cells	Liver
			Down's Syndrome**	Invasion of cells	Frontal lobe of brain, muscle, bones

*Ascending type of muscular paralysis †Febrie episode with sores in mouth ‡Rash and blisters on hand-foot-mouth with fever §Pleuritis type of pain with fever

**Mongolism

Viruses may also have delayed effects. For example, they may be oncogenic (tumor producing) or teratogenic (inducing birth defects). The reported induction of cancer in mice by very small amount of reovirus 3, a member of the group of viruses that are common to man, shows the importance of investigating the impact of non-human viruses on man (13).

Another group of disease causing viruses, the "slow viruses," was not recognized until quite recently. These viruses are extremely small in size and are quite resistant to heat, ultraviolet radiation, formalin and freezing. They have an extremely long incubation period and lead to chronic degenerative disease. These viruses can persist unnoticed in the hosts cells for such a long time because they are able to replicate without causing death to the cell. It has been hypothesized that it may not be the virus, but the response of the body's immune system to infected cells that causes the most damage in these diseases (16).

An outbreak in 1973 of multiple sclerosis, usually a disabling neuromuscular disorder, in the town of Mansfield, Massachusetts, was a cause of much concern as it has been linked to a possible viral contamination of the town's waters between the years of 1932 and 1936 (17). Fourteen confirmed cases of this disease were found in Mansfield, a town with a population of 10,000, giving the town one of the highest multiple sclerosis rates in the nation. Nine of the fourteen people had grown up in the town, and eight had lived within a few blocks of each other, near a pond that was heavily polluted during the years 1932 to 1936. It has been hypothesized that multiple sclerosis is a viral disease contacted at puberty but fails to show any symptoms until early adulthood or middle age. The mean age of the patients from Mansfield in 1934 was 14; this finding concurs with a study by Poskanzer et al (18) in which a mean age of 14 at time of exposure to the disease causing agent was calculated. Although this hypothesis cannot be confirmed, it does point out the great need for research in the characteristics of slow viruses and their mode of transmission.

Survival of viruses in the water environment is influenced by many factors. Generally, they have been found to survive longer at lower temperatures. Also, their survival has been found to be longer in treated or "clear" water or in grossly polluted water than in moderately polluted water (12). This is a contrast to bacteria which survive longer with an increasing degree of pollution. In most waters, viruses appear to last longer and are much more resistant to disinfection and other treatment processes than bacteria. A comparison of survival times of various viruses and bacteria at different temperatures is given in Table 2.

The survival of viruses in sea water may be shortened by a marine anti-viral agent or agents (MAVA). Shuval (11) has studied such agents, and found them to be biological in nature, heat labile, and ether sensitive. They appear to be very complex substances, and not much is known, as yet, of their mode of action.

TABLE 2

EFFECT OF STORAGE: LABORATORY STUDY DEMONSTRATING DAYS

REQUIRED FOR 99.9% REDUCTION OF VIRUSES AND BACTERIA IN SEWAGE (12)

	No. of Days		
	Temperature °C		
Organism	4°	20°	28°
Poliovirus 1	110	23	17
Echovirus 7	130	41	28
Echovirus 12	60	32	20
Coxsackievirus A9	12	..	6
Aerobacter aerogenes	56	21	10
Escherichia coli	48	20	12
Streptococcus faccalis	48	26	14

d. Fungi

Fungi are non-photosynthetic plants that do not form embryo (seeds). They do not have physiologically differentiated or functional roots, stems, and leaves; they consist of one cell or aggregates of undifferentiated cells (10). Some fungi are etiological agents of deep seated and superficial mycoses (fungal infections) in man. They are often found in natural habitats such as soil, and more recently they have been detected in sewage and polluted waters. Cooke and Kabler (19), in a study of sewage effluents, sludges, and polluted waters in southwestern Ohio, reported three pathogenic fungi --Allescheria boydii, Aspergillus fumigatus, and Geotrichum candidum -- to occur consistently. Both Aspergillus funigatus and Geotrichum candidum are etiological agents of pulmonary diseases common to man while Allescheria boydii has been found to cause fungal tumors. Of the three, Geotrichum candidum was most frequently isolated.

2. Hazards in Air-Aerosols

Aerosols are defined as particles ranging from .01 to 50 μ suspended air (20). Aerosols are another potential hazard of wastewater when they are generated from sewage treatment units and spray irrigation systems, as they may contain organisms that are harmful to man. Aerosols that range from two to five μ in size never reach the lungs because they are captured in the upper respiratory tract. Here they are removed by the action of cilia and pass to the digestive tract via the pharynx. (21) If aerosols of this size contain gastrointestinal pathogens, infection may result. Respiratory infections may result from smaller aerosols containing respiratory pathogens. Deposition on the aveoli of the lung is greatest for particles in the one to two μ size range, and then decreases to a minimum at approximately .25 μ. Below .25 μ aveolar deposition increases again (22).

Bacterial pathogens in aerosols have a fairly rapid die-off rate due to dessication in flight. Evaporation rate is directly related to high temperatures, and low relative humidity. Studies of evaporation rates show that a 50 μ water droplet will evaporate in .31 seconds in air with 50 percent relative humidity and a temperature of 22°C (23). Evaporation rate is also affected by the presence of chemical additives. Chemical additives may decrease the rate of water evaporation and thus provide a longer survival time for pathogens (24). Different bacteria have different survival times. E. coli has been shown to have a short life span in the aerosol form while coliforms of the genus Klebsiella, which are pathogens of the respiratory tract, survive much longer as they form a large capsule which protects them from dessication (25).

Both activated sludge and trickling filter units emit considerable numbers of pathogenic particles. Napolitano and Rowe (26) found that activated sludge units emit ten times more coliforms than high rate trickling filters. In activated sludge units, the aeration tanks were found to be the most prolific in discharging bacteria, as significant amounts of coliforms were found at a distance of 150 feet from the aeration tanks with winds varying from 220 to 405 ft/min. Glaser

and Ledbetter (23) found more than 15,000 aerosol particles per cubic foot of air to be emitted from an aeration tank of an activated sludge system. Besides temperature and humidity, these studies found that coliform concentration in the air also depended on size of the source, velocity of the wind, and ultraviolet radiation from the sun.

As for spray irrigation sites, Sepp describes a German study where downwind travel of aerosols increased 85 feet for every 2.25 MPH increase in wind velocity (27). In another study, it was found that with a 5 to 10 MPH wind, the mist zone extended 105 feet downwind from a sprinkler with a spray radius of 30 feet. Because of differences in wind speed, buffer zones of 50 to 200 feet around spray irrigation sites are recommended. Droplet travel may also depend on the spray equipment. High pressure, high trajectory, fine droplets travel further. Aerosol travel may also be decreased by pointing spray nozzles downward and utilizing forested sites that maximize entrapment of droplets (28).

3. Hazards to the Food Chain

Pathogens present in water polluted by sewage may be taken up by aquatic organisms. Shellfish, in feeding, will filter 10 to 20 gallons of water per day through their systems. Shellfish are known to be carriers of bacterial disease agents as in the past many outbreaks of typhoid fever have been attributed to contaminated shellfish. They may also be carriers of viral disease; in fact, 1,700 cases of infectious hepatitis resulting from contaminated shellfish have been reported. Most studies on virus uptake in shellfish have found that most of the common species do concentrate and retain significant amounts of virus, and that, when contaminated shellfish are transferred to clean seawater, the rate of elimination of viruses is considerable in all cases.

Liu et al (29) studied the uptake of poliovirus 1 by the Northern Quahaug and found virus contamination to occur quite rapidly. Most of the viruses appeared to be concentrated in the digestive diverticulum where they were not adsorbed onto, nor did they penetrate, the cells. It was also found that shellfish cleanse themselves quite rapidly when placed in a unit of clean, flowing seawater. Under these conditions, virus concentrations were reduced to a non-detectable level within 48 to 96 hours. Metcalf and Stiles (30) studying shellfish in a New Hampshire estuary found virus survival in oysters to depend on temperature, pollution level, and species of virus. Low temperature caused longer survival; in fact, survival appeared to be indefinite below $4^{o}C$. Survival was also longer at high pollution levels due to the presence of nutrients. Finally, of the three viruses studied, the poliovirus, coxsackievirus, and echovirus, survival of the coxsackievirus was longest and poliovirus was shortest under the same set of conditions. It was hypothesized from data collected in the study, that virus transmission by shellfish would be optimal when high pollution levels and maximum survival times coincide. In the New Hampshire estuary, highest viral pollution of shellfish occurred from July to October and lower water temperatures, which are conducive to longer virus survival, occurred in the early fall. These findings predict

an increased probability for virus transmission via consumption of raw shellfish beginning in midsummer and peaking in early fall. This prediction recapitulates the seasonal pattern described for shellfish induced epidemics of infectious hepatitis in man.

4. Disease Vectors and Nuisance Organisms

Control of disease vectors and nuisances is a major concern in the management of water resources. Unsanitary conditions created by improper management of wastewater often lead to situations conducive to the breeding of vectors.

A vector is an animal which can transmit a communicable disease from an infected person to a well person. In New England, the disease vector of major concern is the Aedes mosquito, a potential transmitter of the Eastern encephalitis virus to man and horses. Of lesser concern are the Anopheles mosquito, a potential vector of malaria, and the American dog tick, a potential vector of Rocky Mountain Spotted Fever (31).

Two species of mosquitoes known to transmit Eastern encephalitis to man, Aedes solicitans and Aedes vexans, are commonly found in New England. Aedes solicitans breeds in brackish pools in salt marshes along the Atlantic coast from Maine to Florida, while Aedes vexans breeds in inland areas along the flood plains of rivers on the muddy edges of receding pools. Both mosquitoes are fierce day biters and have quite long flight ranges (5-20 miles) (32).

The Eastern encephalitis virus, which may be carried by these mosquitoes, can cause a severe and frequently fatal encephalitis in man and equines (horses). In man the disease is usually characterized by a sudden onset with high fever, vomitting, drowsiness or coma, and severe convulsions. In severe cases, death occurs 3 to 5 days from onset. Survivors are often left with mental retardation, convulsions, and paralysis (1). The virus was first identified from the brain of horses in 1933, and was identified as the agent causing an epidemic of man in Massachusetts in 1938-39. In the 1939 epidemic, thirty four cases with 25 deaths were reported, and six out of the nine survivors were left with permanent brain damage (32).

Recent research in the vectors of Eastern encephalitis indicates that birds are the common reservoirs (or carriers) of the virus. The infection chain is normally limited to birds, small mammals, and mosquitoes, with an occasional spillover to horses and humans. The bog or swamp mosquito, Culiseta melanura is the primary vector in the bird-mosquito-bird chain, and rarely bites man, while mosquitoes of the Aedes species transmit the virus to horses and humans. In Massachusetts, only the fresh water swamp mosquito Aedes vexans has been found to transmit the virus. Outbreaks are usually attributed to heavy rainfall, and high temperatures, which cause exceptionally large mosquito populations (31). However, a recent outbreak in Southeastern Massachusetts in August and September 1974 was not preceded by the usual chain of events leading to and Eastern encephalitis outbreak. The Regional Office of the Department of Public Health in Lakeville, which tests mosquito pools in the summer

months for the encephalitis virus, could not isolate the virus from the man biting Aedes mosquito. Only the vectors in the bird-mosquito-bird chain, Culiseta melanura, appeared to be infected in 1974. In addition, there was less rainfall in this section of Massachusetts than there was in previous years. However, there was a larger population of Culiseta mosquitoes, as this mosquito can overwinter in its larval form and heavy rainfall the previous year had produced a large overwintering population (33).

Three cases of the virus were reported during late summer 1974 to the Massachusetts Department of Public Health (one in Taunton, one in Foxborough, one in Middleborough). One death was reported as of September 1974.

Mosquitoes and other insects may also create great annoyance problems for man. The domestic mosquito Culex pipiens breeds in urban areas in streams, street catch basins and clogged drainage ditches containing water of high organic content. Numbers of this mosquito have increased over recent years due to the increase of polluted water in urban areas (31). This mosquito is not an aggressive biter; however, it invades houses, and its persistant high pitched hum continued late into the night makes it a considerable pest (32).

Horseflies and deerflies are another nuisance problem in eastern Massachusetts. These flies inhabit marsh areas, creating severe annoyance at recreational and work sites, as their bites create fairly deep, painful wounds causing considerable flow of blood (32).

Biting midges are a nuisance in coastal resort areas, freshwater inlets, and tidal pools. Non-biting midges also create problems. They breed in brackish water, tidal creeks, and fresh water ponds. Usually high organic concentrations in the water will favor production (31). Swarms of these insects have interfered with human activities and comfort, and have been known to cause traffic hazards when crossing highways (32).

It is predicted that vector and nuisance problems will increase in the future due to the rapid increase in population, the development of suburban areas close to breeding places, the expanded use of recreation areas, inadequate control of wetlands, concern over pesticide use, and the development of insect resistance to various pesticides. To combat this growing problem, research, surveillance and technical assistance must be provided in problem areas, along with an increase in size, number, and scope of mosquito control programs with more emphasis on water management and source reduction.

In Massachusetts, encephalitis surveillance is handled by the Lakeville Regional Office of Public Health. The State Reclamation Board, has the responsibility for supervision of all organized mosquito and nuisance control projects.

B. Chemical Hazards

1. Hazards in Effluents and Sludges

Chemical agents found in wastewater may pose a threat to the public health as they can contaminate water supplies and become concentrated in mans food supply. Some chemicals may be present in such quantities that they create acute toxic effects when ingested, while others accumulate in the body in small quantities over a long period of time, producing long term chronic disease. Small concentrations of chemicals such as trace metals may never produce overt disease but do cause such subclinical effects as fatigue, headache, and nervousness that are never brought to the attention of a physician or never linked to chemical toxicity.

A substance is considered toxic "if it impairs growth, reproduction, or metabolism of an organism when supplied above a certain concentration" (34). Even elements essential to life may be toxic above certain concentrations. Animals have the ability to eliminate and detoxify many chemical toxins entering the body. Schroeder states that "toxic action occurs only when homeostatic mechanisms for excretion are overcome" (35).

Substances found in wastewater that may be toxic to man and other forms of life are trace metals, cyanides, nitrates, pesticides, some organic compounds and radioactive substances.

a. Metals

Metals are some of the most dangerous elements in our environment. Rapid increase of industrialization has caused the release of these elements into the environment in enormous amounts. "The last half century has demonstrated all too clearly that biological adaptive processes are too slow to cope with the environmental change induced by technology" (36). Although much is known about the toxic effects of large doses of metals, less in known about the effects of long term small doses on biological systems, food chains, and humans.

Many metals, when present in small quantities, are essential to life. Shroeder lists 14 "good" metals (37). Four that are needed in bulk quantities are: sodium, magnesium, potassium, and calcium. Ten that are needed in very small quantities are: vanadium, chromium, manganese, iron, cobalt, copper, zinc, selenium, strontium, and molybdenum. Metals are "bad" when they accumulate with age, and are present in quantities greater than what is necessary for life and health. There is no cellular requirement at all for some metals such as lead and mercury. Certain metals may also react with others to cause synergistic effects (caused when the danger from two combined pollutants is greater than the sum of individual dangers). Such is the case with arsenic and lead, which when present together, have increased toxic effects (38).

(1) Trace Metals

Mercury

For a long time, large concentrations of mercury have been known to produce a disease called "hatters madness," which was common in the felt handling trade due to the use of mercuric nitrates in the felt making process. Industrial control of mercury came early, although these controls applied only to inorganic mercury and large doses. The danger of organic mercurials, such as methyl mercury, which are far more toxic than inorganic mercurials as they accumulate in the human body was not recognized until recently. The main impetus for research into the toxicity of organic mercury arose from a severe outbreak of mercury poisoning in Minimata, Japan during the 1950s. Minimata, a coastal town with a population of 10,000 experienced an outbreak of a strange disease causing loss of coordination, numbness of limbs, blindness, and loss of hearing. Forty three people died and 68 were left permanently disabled (36). One third of these cases appeared in infants born to undiseased mothers. In such cases, the disease was especially severe, causing deformity, mental retardation, lack of muscular control, and early death. Extensive investigations found that local factories using mercuric sulfate as a catalyst in manufacturing acetaldehyde were discharging process water high in concentrations of inorganic mercury to Minimata Bay. It was further found that fish and shellfish in the Bay contained 1-3 and 5-20 ppm organic mercury (wet weight). Since fish and shellfish played a major role in the diet of the inhabitants of this coastal town, a linkage between organic mercury and "Minimata" disease could be established. However, the inorganic mercury in the factory effluent could not be linked to the organic mercury in fish and shellfish until it was later found that inorganic mercury can become methylated to form organic mercury by microbial action in anaerobic conditions.

Organic mercury is more toxic than inorganic mercury because of its chemistry (32). It accumulates in humans because it can become firmly bound to various proteins and fats which make up the cells of the body. Because it is so tightly bound, its half life (length of time needed for a system to rid itself of half the substance absorbed) is much longer. Organic mercury can concentrate in the liver, kidney, and brain; and it has a different half life in each of these different organs. The half life in the brain and fetus is particularly long even though they have slow rates of uptake. This explains the devastating effect organic mercury has on the nervous system and on newborn children. Organic mercury also has an extremely serious effect on the nervous system because we are endowed with a limited number of brain cells at birth. These cells and the neural pathways connecting them do not have the ability to reproduce or repair themselves. When damage is done to these cells and pathways of the brain, it is usually irreversible. In addition, extensive damage must occur before effects can be seen because many neural pathways are not absolutely necessary for a function to be carried out, but merely duplicate other pathways in case of breakdown. Thus, a large number of people in Minimata may have suffered a great amount of brain damage through destruction of these

duplicate neural pathways without clinical symptoms. Children may be more sensitive to the toxic effects of mercury because they have fewer neural pathways thus leaving themselves open to more widespread damage.

Mercury can also cause genetic damage as it has been known to cause chromosome division at concentrations as low as .05 ppm (39).

Mercury enters the environment through the burning of natural fuels, the extraction and use of mercury itself in mining, smelting, and refining, the manufacture of chemicals and paper, and its use as a fungicide in agriculture. Many feel that mercury is a problem only in fresh water and not in the ocean because it can become greatly dispersed in large volumes of ocean water. However, "hot spots" may be created in ocean water because mercury becomes firmly bound to the sediments, and when methylated, it is rapidly taken in by organisms. Mercury can become a great problem in estuaries and fresh water. In 1970, fish in Lake St. Clare and the St. Clair River on the Canadian border were bound to contain as much as 7.8 ppm mercury (39). Scientists in Sweden found that the mercury concentration in pike, which is at the top of the aquatic food chain, ranged up to 17 ppm in the skin (40).

Many estimates have been made as to the threshold level for mercury poisoning in man. Scientists at the Oak Ridge National Laboratory, using a safety factor of 10, set the allowable daily intake at about 100 micrograms/day (41). The present USPHS Drinking Water Standards have no limit for mercury, and the new proposed Drinking Water Regulations set the maximum acceptable concentration for mercury in public water supplies at 2 ug/l(42). The Swedish standard is .03 mg/day (30 micrograms/day) assuming two meals of fish a week (39). The FDA interim standard for mercury is .5 ppm for fish and .2 ppm for shellfish. To set a definite threshold value, further research is needed in the mechanisms of mercury toxicity in man.

Lead

Lead is another dangerous trace metal that, like mercury, has no useful function in the human body. Lead is also similar to mercury in other aspects as it is more potent in its organic forms; it has a more devastating effect on infants and children; and it can cross the placental barrier and damage the fetus. Lead poisoning may be either acute or chronic, although the latter is most common. Early symptoms of chronic lead poisoning are listlessness, anemia, abdominal pain, and vomitting. Chronic lead poisoning can eventually lead to extensive liver and kidney damage, peripheral nerve disease, permanent brain damage and genetic damage (43, 44, 45).

The normal blood lead level in humans ranges from 15 to 40 ug/100 ml of blood (37). The threshold blood lead level for lead poisoning is not known. Some researchers have placed the threshold level as high as .7 ppm to .8 ppm (70 - 80 ug/100 ml), while other researchers in Great Britain have calculated the safe threshold level for children to be .36 ppm (46). Levels of lead as low as .20 ppm blood have been shown to inhibit the enzymes necessary for the

biosynthesis of heme (which combines with a protein to form hemoglobin) (47).

Lead accumulates in the body with age in the bone and sometimes the aorta (35). The normal human intake of lead has been estimated to be 300 ug/day, and the average person can excrete 500 ug/day. However, if lead levels in the environment are above normal a person may easily accumulate small quantities over a period of time. This accumulated lead may become dangerous as "under conditions of high calcium metabolism, such as feverish illness of cortisone therapy, lead may be mobilized, and a toxic amount is released from the skeleton" (44). Schroeder believes that innate lead toxicity is common among city dwellers causing tiredness, nervousness, apathy and lack of ambition (37).

Major sources of lead are food and the atmosphere. Lead from the atmosphere may enter the water environment in atmospheric fallout from motor vehicles and industry. Drinking water may also be contaminated with lead from lead piping especially in areas where there is soft, acidic water to dissolve the lead. The present WHO and USPHS Drinking Water Standards as well as the new proposed Regulations, set the limit for lead in public water supplies at .05 mg/l (6, 42).

<u>Cadmium</u>

Cadmium is another trace metal that may reach toxic amounts in water. Acute cadmium poisoning may cause gastroenteritis. Long term exposure to small doses may cause chronic disease with first symptoms of tiredness, shortness of breath, an impaired sense of smell, and painful joints, and later symptoms of decalcification of the skeleton, bone fractures, and kidney malfunction accompanied by excessive excretion of proteins, amino acids, glucose, and calcium (48). A classic outbreak of this disease occurred in Japan along the Jintsu River in Toyama Prefecture. From World War II to the 1960s, over 200 cases of this disease (called "itai-itai" because of the patient's shrieks of "itai-itai," as they suffered severe pain in their bones) were reported. The water from the Jintsu River, which was contaminated with cadmium, lead, and zinc from nearby mining tips, was used to irrigate rice crops, and by many, as a source of water supply. Kobayashi (48) made a study of this disease outbreak and found that cadmium, lead, and zinc were not only present in high concentrations in the water but also in the irrigated rice. He then studied the effects of these three metals on rats, and found that cadmium alone caused symptoms characteristic of the disease.

Cadmium is accumulated with great efficiency in the kidneys and liver and to a lesser extent in the pancreas, spleen, thyroid, adrenals, gall bladder and testes (49, 50). In mammals, cadmium becomes bound in the kidney as a metalloprotein and is released very slowly. From an average daily intake of 200-500 ug of cadmium, the average person retains 1.8 to 3.6 ug (49). It has been found that the cadmium concentration in mans kidney increases until approximately age 50. Cadmium has been implicated in hypertensive disease. Schroeder found that extremely low doses of cadmium (only a few hundred micrograms), when injected into the blood stream of small animals, produced increased

blood pressure (51). In another study, Schroeder created a cadmium free environment for experimental animals, and then found that the addition of five micrograms/l cadmium to the drinking water of a portion of these animals caused a shortened life span, thickening of the small arteries of the kidney, hardening of the arteries, enlargement of the heart, high blood pressure, and high cadmium concentration in both the kidneys and blood vessels (52). These findings duplicate the findings in high blood pressure of humans. A study around the world showed that people dying of hypertension had more cadmium in their kidneys and a higher cadmium/zinc ratio than people dying of other causes (52).

Cadmium has also been found to be associated with kidney damage, cirrhosis of the liver, and damage to the lungs. Many studies have indicated that cadmium is a carcinogen. Experiments on animals have shown cadmium to cause damage to the central nervous system. Cadmium may also cause destruction to the testicles and placenta (53).

Both the present and proposed Drinking Water Regulations set the maximum allowable level for cadmium at .01 mg/l. This value is exceeded in many cities due to soft water and galvanized pipes (zinc ore contains cadmium) (54). Soft water has the ability to dissolve metals in pipes and has been linked to cardiovascular disease. It has been hypothesized that it is not soft water, but the metals, such as cadmium dissolved by soft water, that are related to cardiovascular disease (52). Large amounts of cadmium are released into the environment each year from processing and refining of cadmium bearing ores, the incineration of cadmium containing products, the electroplating industry, the battery industry, and the use of phosphate fertilizers mined from deposits with sedimentary bands of fossiled fish teeth (which contain a lot of cadmium) (54). Cadmium may also enter the food chain of man by becoming concentrated in plants and shellfish.

Arsenic

Ingestion of as little as 100 mg of arsenic can cause severe acute poisoning (6). Chronic poisoning with arsenic is more common, as arsenic is easily absorbed from the gastrointestinal tract and lungs and becomes distributed throughout the blood and tissues, inhibiting enzymes needed for cellular oxidation (55). Arsenic is mildly toxic in its pentavelent (+5) oxidation state, and highly toxic in its trivalent (+3) oxidation state. Arsenic, like mercury, may become methylated in the water environment: however, while organic arsenic in the air is highly toxic, organic arsenic concentrated in fish from water is of low toxicity. Also, although aquatic organisms concentrate arsenic from water, it is not progressively concentrated along the food chain (55). Many arsenic compounds have been implicated as being carcinogenic to humans: however, experimental results do not support this hypothesis (56).

Arsenic may react with other metals in the environment. It may decrease the toxic effect of selenium, but it increases the toxic effect of lead. Arsenic enters the environment through natural processes, through the burning of fossil fuels, the mining and processing of sulfide minerals, the increased erosion of the land, and to a much lesser extent,

through the use of phosphate detergents and fertilizers (55). The new proposed national drinking water regulations set the maximum allowable concentration of arsenic in public water supplies at 1.0 mg/l (42).

Chromium

Ingestion of chromic acid and hexavalent salts of chromium, in large amounts, can cause irritation of the gastrointestinal tract with vomitting and diarrhea, and irritation of the skin (56). In most of its soluble forms, however, the toxicity of chromium is quite low. Inhaled hexavalent chromium has been shown to be carcinogenic, and chromate ore roasts and a few selected chromium compounds have induced malignant tumors in subcutaneous and muscle tissue when implanted at certain sites in rats and mice (57). However, no carcinogenic effects from ingested chromium have been found. Although not enough is known about chromium toxicity in humans, present USPHS Drinking Water Standards and the new proposed Drinking Water Regulations set the maximum allowable limit for chromium at .05 mg/l. Schroeder and others have shown that chromium is an essential micronutrient effecting growth and survival (58). Chromium has been found to be a protective agent against lead toxicity in rats (59). Concentrations of less than 5 - 8 ppb indicate a deficiency state in humans, as low states of chromium in the body may impair glucose tolerance (58). Chromium salts may enter the water environment from tanning and plating industry wastes, and from industries producing paints, dyes, ceramics, and paper.

Copper

Copper is only moderately toxic to humans. Ingestion of large amounts (above 50 ppm) of copper salts causes vomitting, gastric pain, dizziness, cramps, convulsions, and sometimes death (60). Concentrations in water are usually too low to cause these symptoms. There is no evidence of chronic copper poisoning as it does not accumulate in the body. However, if emesis does not occur when large amounts are ingested, systemic copper poisoning may result causing damage to the capillaries, liver, kidney and central nervous system (60). Copper is used in the metallurgical, electroplating, pesticide, electrical, textile, munitions, and photographic industries.

Small amounts of copper in drinking water may be beneficial, as copper is an essential micronutrient. Both present and proposed Drinking Water Regulations set the maximum allowable limit for copper at 1 mg/l (6).

Selenium

Selenium is toxic to man in certain forms; however, the most toxic selenium compounds are found in the air environment. Water and soil may become contaminated with selenium through industrial fallout. Selenium compounds have been known to cause depression, nervousness, gastrointestinal disturbances, and garlic odor of the breath and sweat (61). Selenium in small amounts may also be capable of increasing dental caries if consumed during tooth development (62). Despite these harmful effects, trace amounts of selenium may be necessary in the

diet. It has been found that chicks receiving diets inadequate in selenium suffer severe malfunction of the pancreas, a breakdown in the digestion of dietary fats, and a breakdown in vitamin E adsorption (63).

There appears to be conflicting findings on the carcinogenicity of selenium (57). Selenium may have an inhibitory effect on cancer development, as studies have found that sodium selenide reduces the number of artificially induced tumors in mice (64). Other studies have found an inverse relation between sodium selenide in soil and forage crops and human cancer rates and an inverse relation between human blood levels of selenium and human cancer rates (65). Both present and proposed Drinking Water Regulations set the maximum limit for selenium at .01 mg/l (6, 42).

Antimony

Antimony, in low concentrations, has been known to shorten the life span in small mammals (66), and may have quite damaging effects on the heart and liver (67). No detailed studies have been done on the long term effects of antimony, although it is quite widely used in the manufacture of paints, textiles, rubber, and ceramic glazes.

(2) Other Metals

Sodium

Sodium is an essential nutrient to all animals, and deficiency of this substance produces primarily a failure to grow and survive. Much attention has been given to sodium lately as it has been linked with the development of high blood pressure. In studies where rats have been fed high concentrations of sodium salt, some researchers have found a relationship between high sodium diets and high blood pressure, while others have found the occurrence of high blood pressure to be hereditary (68). Sodium has also been implicated in cardiovascular disease. Water softened by sodium cycle ion-exchange resins is high in sodium, and soft water has been found to be directly related to cardiovascular disease. However, sodium is also often found in waters with high mineral content (hard waters), which are inversely related to cardiovascular disease. The conflicting relationships between sodium concentration and water hardness indicate the need for further research on the subject. Because sodium does have a beneficial effect on man in concentrations normally found in water and sodium concentrations in food are often much higher than the sodium concentrations of water, there are no regulations for the amount of sodium in drinking water.

Hardness

Hardness in water is caused by the presence of cations of elements such as calcium and magnesium. Recently many studies have found hardness of water to be inversely proportional to cardiovascular disease. Schroeder et al, in a study of 163 cities in the United States, found that Ca^{++} and Mg^{++} correlate well with male death rates from coronary heart disease (69).

Most recently, a study in England compared men living in soft water towns to men living in hard water towns in terms of indicators of cardiovascular disease. Men in both groups were matched according to social class, occupation, and way of life. Men from soft water towns had higher blood pressure, plasma cholesterol, heart rate, and cardiovascular mortality rates than men in hard water towns (70).

b. <u>Nitrogen compounds</u>

Nitrogen is essential to all living things, although in some forms, and at certain concentrations, it presents a hazard to the health of both man and animals. In recent years, there has been a marked increase in the nitrogen concentration of both surface and groundwaters in the United States due to increased municipal and industrial waste discharge (both effluents and sludge), septic tank discharge, and runoff from dumps and animal feedlots. Non point sources such as runoff, leaching, and tile drainage from agricultural, urban, and other lands also play an important role in the increased nitrogen content of our waters (71).

Humans are being exposed to large amounts of nitrogen in both their food and water. Vegetables such as beets, spinach, and broccoli accumulate large quantities of nitrate due to increased application of fertilizers: meat may also be high in nitrates due to a nitrate-nitrite preservative widely used in the meat processing industry (71). Present and proposed Drinking Water Regulations set the limit for nitrogen (NO_3) at 45 mg/l. Most surface water supplies in the United States comply with this limit, however, many groundwater supplies in rural areas do not, due to agricultural contamination. Thus, nitrates are of great concern in considering wastewater reuse by recharge to an aquifer.

Excessive concentrations of nitrates and nitrites in humans can lead to a condition called methemoglobinemia. Ingested nitrites and nitrates (which can be converted to nitrites by the human intestinal bacteria) can convert the hemoglobin of the blood to methemoglobin. Hemoglobin is the oxygen carrying component of blood, which when converted by nitrites to methemoglobin, loses its ability to combine with oxygen. Cyanosis (bluish tinge to the skin) and disturbances of bodily functions, due to lack of oxygen, may occur when five to ten percent of the total hemoglobin has been converted to methemoglobin. Since 1944, over 2,000 cases of this disease have been reported (71). Most cases occur in infants under three months of age because: (72)

1. Fetal hemoglobin is more readily converted to methemoglobin.

2. Infants are deficient in two enzymes necessary to convert methemoglobin to hemoglobin.

3. Infants have a high fluid intake per body weight.

4. The stomach of an infant is at a lower pH, which is more conducive to growth of bacteria which converts nitrates to nitrite.

5. Gastrointestinal illness in infants permits bacteria responsible for nitrate conversion to nitrite to move higher in the gastrointestinal tract.

Many subclinical cases of nitrate poisoning must exist. A study of Pethukov and Ivanov showed a slowing of conditioned motor reflexes in response to auditory and visual stimuli in children whose water contained only 26 mg/l nitrogen as nitrate (73).

c. Cyanide

Small doses of cyanide (CN) may act as a respiratory stimulant, but at higher doses, it acts as a respiratory depressant. Large doses of cyanide may paralyze the central nervous system, and arrest respiratory movement and beating of the heart (60). The safe threshold of cyanide has been determined to be 19 mg/l (as CN) and doses over 50 - 60 mg may be fatal (6). Smaller doses of cyanide (5 - 10 mg) are detoxified, mainly in the liver, where they are converted by enzymes to thiocyanate (a non toxic sulfur complex) (6). Detoxification mechanisms in humans are usually inexhaustible, although toxic effects do occur when the rate of cyanide adsorption surpasses the rate of detoxification. Prolonged administration can cause an undersupply of oxygen to the body's cells, destruction of nerve fiber casings, and changes in the thyroid (60). Both present and proposed Drinking Water Regulations set a limit for cyanides in public water supplies at .2 mg/l/

d. Pesticides

Pesticides are chemical agents used to kill unwanted species or pests. The increased production and use of these substances has been the cause of much concern in recent years, as in large quantities they have been proven highly toxic to man and wildlife; and at persistant low levels, they have been liked to cancer in man. Most of the pesticides used today are of the synthetic organic type: the two most popular forms are the chlorinated hydrocarbons and organophosphates.

Chlorinated hydrocarbons such as DDT, Dieldrin, Aldrin and Lindane eliminate pests through their action on the central nervous system (74). Unfortunately, they may also affect the nervous system of other animals and man in high amounts, and may have harmful chronic effects on vertebrates at low levels. Such effects include fatty infiltration of the heart, and fatty degeneration of the liver. Chlorinated hydrocarbons are dangerous for three basic reasons (75). First of all, they are non specific universal poisons, killing other species besides the pest. Secondly, they are not biodegradable, and can persist in the environment for long periods of time. Finally, they are able to concentrate in the fat of man and animals. This last point causes the biological magnification of these substances in the food chain. Animals occupying higher positions in the food chain have smaller populations, yet these smaller populations are exposed to higher concentrations of pesticides. Fish and other aquatic animals and fish eating birds are especially sensitive to these substances. Many lakes and streams contain fish with DDT levels above 5 mg/kg, the alert level

set by the Food and Drug Administration. Lake trout reproduction has been inhibited by DDT. Concentrations of 5 ppm in trout eggs have been known to kill fry when they adsorb their final yolk sac before hatching (76). Chlorinated hydrocarbons have also been proven to produce reproductive difficulties in birds by interfering with their ability to metabolize calcium. This interference decreases the thickness and weight of the eggshell, causing it to break (76). Many other effects on smaller animals are known, but not much is known of the effects of these pesticides on man. They have been indicated as carcinogens, but evidence is not conclusive. Man already contains high concentrations of these substances, and it is disturbing to note that an average mother's milk contains .05 - .26 ppm DDT (74). The FDA limit for DDT in milk is .05 ppm!

Organophosphates such as Parathion, Malathion and Azodrin are more toxic than chlorinated hydrocarbons, but less stable and less persistent in the environment (74). These pesticides are cholinesterase inhibitors. They inhibit the enzyme responsible for the breakdown of nerve transmitter substances, causing acute activity of the nervous system and death. Because of their lack of persistence, these substances have not been indicated in chronic disease; in fact, mammals have enzymes that can break down Malathion.

The LD_{50} (oral dose lethal to 50% of the exposed laboratory animals, in mg/kg) of various pesticides is given in Table 3 (77).

Pesticides enter the aquatic environment by direct application to surface water (as in the case of mosquito larvicides), water runoff, and particulate erosion from contaminated land. In metropolitan areas, these substances may be discharged through sewers to sewage treatment plants where they may impair treatment processes by sterilization of micro-organisms (76). Pesticides cannot be removed from water and wastewater by most treatment processes; the activated carbon adsorption process seems to be most effective. Care must be taken as their degradation products may be just as harmful, if not more harmful, than the pesticides themselves (76). In aquatic systems, pesticide concentrations decreases with time, as their concentrations increase in sediments and aquatic organisms. However, it may be possible that concentrations in sediments can recycle to the water phase. Pesticides usually don't reach the ground water as they are readily adsorbed on soil particles when applied to the land, and are very difficult to leach out (76). The major mechanisms for their dissipation in the environment are adsorption, degradation, volatilization, and plant uptake. New proposed limits for pesticides in drinking water are given in Table 4.

e. Organic Compounds

Other organic compounds are becoming increasingly present in the nations waters. A report by A. D. Little for the Environmental Protection Agency in December 1970 (78) found 469 reported or suspected organic chemicals in drinking water. Organics such as phenols, pyridine, diphenyl ether, kerosene, nitriles, PCB (polychlorinated biphenyls) and benzene derivatives are suspected carcinogens. While carcinogenic effects on animals have been experimentally proven, extrapolation of these results

TABLE 3 (77)

TOXICITY OF THE MORE COMMON PESTICIDES

AS SHOWN BY THEIR LD/50s (mg/kg)

Organochlorine Group

Aldrin	55
Benzene hexachloride	500
Chlordane	457
Dieldrin	60
Endrin	10 to 12
Heptachlor epoxide	40 to 60
Methoxychlor	6000
DDD	8400
DDT	113
DDE	880
Diazinon	100 to 150
Lindane	125
Simazine	5000
2,4,5-T	100
2,4-D	560
Toxaphene	90
Atrazine	1750

Botanicals

Allethrin	680
Barthrin	680
Pyrethrins	820 to 2600
Ryania	1200
Rotenone	132
Sabadilla	4000
Warfarin	58(F) 323 (M)

Organophosphorous Group

Ethion	27 to 65
Guthion	16.4
Parathion	6 to 15
m Parathion	9 to 25
Malathion	1000 to 1375
Dibrom	430

Others

Fenuron	6400
Calcium cyanamid	42
Silvex	650
Carbaryl (Sevin)	540
Ferbam	7000

TABLE 4

PROPOSED MAXIMUM CONTAMINANT LEVELS FOR CHLORINATED HYDROCARBON INSECTICIDES IN PUBLIC WATER SUPPLIES

Compound	Water Recommended 1/ limit (mg/1)
Chlordane	0.003
Endrin	0.0002
Heptachlor	0.0001
Heptachlor epoxide	0.0001
Lindane	0.0005
Methoxychlor	1.0
Toxaphene	0.005

1/ Assume average daily intake of water for man - 2 liters.

to humans is difficult and uncertain (79). The toxicity of the breakdown products of these chemicals must also be considered: and many of them may react together to produce synergistic effects (80). For example, benzyprene and certain detergents react together to produce cancer in animals: however, alone they do not. Methods of control of these substances are still in their infancy. Drinking water standards do not exist for many of them as these standards were developed for relatively clean protected waters not water heavily polluted by industry (80). Also, most conventional treatment methods are ineffective in removing such exotic wastes.

2. Hazards to the Food Chain

a. Trace Metals

Trace metals may be taken up by aquatic organisms living in waters polluted by industrial effluents. Trace metal concentrations in the marine biosphere are higher than in the hydrosphere (34). It has been proven that these substances can become concentrated in mollusks up to many hundred times the level found in the marine environment. Several pathways of this concentration process have been suggested (81):

1. Particulate ingestion of suspended material
2. Ingestion through preconcentration in the food chain.
3. Complexing of metal by linkages with appropriate organic molecules
4. Incorporation of metal ions into physiologically important systems of the mollusk
5. Uptake by exchange, for example, onto the mucous sheets of the oyster

Studying various species of estuarine mollusks, Pringle et al (34) measured the concentration levels, uptake rates, and depletion rates of selected trace metals under various conditions. Average trace metals levels in shellfish taken from 100 sampling stations along the Atlantic coast are given in Table 5. Trace metals accumulation by various species of shellfish in a simulated natural environment were also studied; these results are given in Table 6. It has been found that the food chain and sediments may contribute some metals, although most metals are taken up in their soluble phase from surrounding waters (82). Experimental results of this study indicated that accumulation rates depend on temperature, condition of the particular shellfish, pollution levels, and the physiological role the metal plays in the body of the shellfish. Pringle also found accumulation rate to be greatest in the soft shell clam and least in the hard shell clam.

Depletion rates of different trace metals in shellfish were also measured; the results of these experiments are given in Table 7. Pringle found that these substances become chemically and structurally

TABLE 5

AVERAGE TRACE METAL LEVELS IN SHELLFISH TAKEN FROM ATLANTIC WATERS (34)

(Values are Given in PPM Wet Weight)

Element	Eastern Oyster	Soft Shell Clam	Northern Quahaug
Zinc	1428	17	20.6
Copper	91.50	5.80	2.6
Manganese	4.30	6.70	5.8
Iron	67.00	405	30
Lead	.47	.70	.52
Cobalt	.10	.10	.20
Nickel	.19	.27	.24
Chromium	.40	.52	.31
Cadmium	3.10	.27	.19

TABLE 6

TRACE METAL ACCUMULATION STUDIES IN A SIMULATED NATURAL ENVIRONMENTAL SYSTEM (34)

Environmental Level	Values mg./kg. Initial	Final	Total Accumulation	Accumulation Time in Days	Acculation Rates (mg.kg./day)	Species	Sea Water Temperature
.1 ppm	23	79	56	10	5.60	Soft Shell	20°C
.2ppm	15	85	70	25	3.00	Soft Shell (Toxic-poor condition)	20°C
.05 ppm	35	200	165	8	20	Soft Shell	No Control (25-26°C)
.5 ppm	6.5	8	1.5	25	.06	Quahaug	No Control (10°C)
.2 ppm	10	27	17	50	.35	Soft Shell	20°C
.05 ppm	0	8 (3.8 in 4 wks)	8	70	.10	Soft Shell	20°C
.1 ppm	0	9 (6.5 in 4 wks)	9	56	.16	Soft Shell	20°C
.1 ppm	0	112	112	70	1.60	Soft Shell	20°C
.2 ppm	0	235	235	40	5.80	Soft Shell	20°C
.2 ppm	0	260 (220 in 70 days)	260	84	3.10	Soft Shell	20°C
.2 ppm	0	35	35	56	.63	Quahaug	20°C
.025 ppm	0	17	17	49	.35	Eastern Oyster	20°C
.05 ppm	0	35	35	49	.71	Eastern Oyster	20°C
.1 ppm	0	75	75	49	1.50	Eastern Oyster	20°C
.2 ppm	0	200	200	49	4.00	Eastern Oyster	20°C

TABLE 7

TRACE METAL DEPLETION STUDIES IN A CONTINUOUS FLOW SYSTEM (34)

Species	Metal	Depletion Range, in milligrams per kilogram per day Initial	Final	Depletion Time, in days	Temperature, in degrees Celsius	Depletion Rate, in milligrams per kilogram per day	Source of Specimens
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Soft Shell	Copper	124	36	7	20	12.50	from 0.1 ppm accumulation study
Soft Shell	Copper	96	34	11	20	5.10	River View (water off)
Soft Shell	Copper	68	9	10	20	5.90	Allens Harbor
Soft Shell	Copper	62	34	4	20	7.00	Long Meadow (water off)
Soft Shell	Copper	58	20	15	20	2.60	Jerusalem (water off)
Soft Shell	Copper	52	24	15	20	1.90	Allens Harbor (water off)
Soft Shell	Copper	48	22	4	20	6.50	from 0.2 ppm accumulation study
Soft Shell	Copper	33	20	7	20	1.90	Charlestown
Hard Shell	Copper	17.5	13.0	84	no control (4-12)	0.05	Boston Harbor
Hard Shell	Manganese	21	16	84	no control (4-12)	0.095	Boston Harbor
Hard Shell	Zinc	38	26	84	no control (4-12)	0.12	Boston Harbor
Hard Shell	Iron	27	37	84	no control (4-12)	0.0	Boston Harbor
Oyster	Lead	200	188	21	20	0.71	from 0.2 ppm accumulation study
Oyster	Lead	79	60	21	20	0.76	from 0.1 ppm accumulation study
Oyster	Lead	32	22	21	20	0.48	from 0.05 ppm accumulation study
Oyster	Lead	24	5	21	20	0.91	from 0.025 ppm accumulation study

incorporated into the tissues of the various organs of the mollusk and essentially become an integral part of the animal. Thus, biological turnover, or depletion, depends on the reversal of the incorporation process. The depletion rates for metals contamination were found to be much slower than those for biological contamination. In general, depletion rates for each species were directly proportional to uptake rates, that is, depletion was fastest in the soft shell clam and slowest in the hard shell clam. Depletion also seemed to depend on the initial concentration of the metal in the shellfish.

Although much information exists on accumulation and depletion of metals in shellfish, very little is known about these processes in fish and crustaceans. It is known that fish do accumulate metals but not to the degree found in mollusks. There is evidence that metals such as chromium and cadmium do not accumulate in the edible portion of the fish (83). Lobsters and crabs also take up metals, but again, in smaller quantities than shellfish (84). Higher accumulation rates in shellfish can be easily explained; they pump a large quantity of water through their bodies each day to strain out essential nutrients, and through this process, they also accumulate a lot of non essential substances.

The National Shellfish Sanitation Program of the Food and Drug Administration has proposed alert levels for trace metals in shellfish (85). These levels were proposed for the sole purpose of acting as indicators of changes in trace metals concentrations in shellfish growing waters; they do not reflect levels dangerous to man, as not enough information exists on heavy metals toxicity in man. Alert levels for trace metals in shellfish are listed in Table 8.

b. Pesticides

Tons of pesticides are released into the environment each year due to agricultural practices, industrial discharges, and pest control. Large percentages of these substances eventually reach rivers and estuaries where they are taken up by marine organisms, such as fish and shellfish, that are used for food purposes. The Food and Drug Administration has not set levels for these substances in fish; however, the National Shellfish Sanitation Program has proposed alert levels (see Table 9) for pesticides in shellfish (85). The Program has further recommended that if combined values obtained for Aldrin, Dieldrin, Endrin, Heptachlor, and Heptachlor epoxide exceed 0.20 ppm, such values be considered as alert levels which indicate the need for increased sampling until results indicate the levels are receding. It has also recommended that when the combined values for the five pesticides exceeds 0.25 ppm, the shellfish harvesting area should be closed until levels recede.

TABLE 8

PROPOSED ALERT LEVELS FOR TRACE METALS IN SHELLFISH (ppm) (85)

Metal	Oyster	Quahaug	Soft Shell Clam
Hg	.2	.2	.2
Cd	3.5	.5	.5
Pb	2.0	4.0	5.0
Zn	2000	65	30
Cr	2.0	1.0	5.0
Cu	175	10	25

TABLE 9

PROPOSED ALERT LEVELS FOR PESTICIDES IN SHELLFISH (ppm) (85)

Aldrin	.20
BHC	.20
Chlordane	.03
DDT) Any or all DDE) not to exceed DDD)	1.5
Dieldrin	.20
Endrin	.20
Heptachlor	.20
Heptachlor expoxide	.20
Lindane	.20
Methoxychlor	.20
2, 4-D	.50

II. EFFECTIVENESS OF WASTEWATER TREATMENT IN TERMS OF PUBLIC HEALTH

A. Water-Oriented Treatment

Most of our nation's treatment plant effluents are discharged into nearby waters, where they may pose the threat of contamination to drinking water supplies, recreational areas, and food supplies taken from these waters. Wastewater from many communities in the Boston Harbor Eastern Massachusetts study area receive only primary treatment. Due to concern over pollution of our nation's waterways, the Federal Water Pollution Control Act Amendments of 1972 and the current State-EPA implementation plan call for a minimum of secondary treatment for all municipal facilities. In some areas, secondary treatment exists. The proposed alternatives in this study include secondary treatment for effluents discharged into the ocean, and advanced wastewater treatment for effluents discharged to inland waters. An evaluation of both existing and proposed treatment methods in terms of their effectiveness in the removal of biological and chemical contaminants is provided in this section.

1. Removal of Biological Hazards

As wastewater is often discharged into the waters that are eventually used for recreation or a source of drinking water supply, it must receive adequate treatment to eliminate potentially pathogenic organisms. The various methods of wastewater treatment vary in their ability to effectively remove these pathogenic agents. In this discussion, emphasis will be placed on virus removal, as many viruses have been found to be more resistant to treatment processes than bacteria. Also, current disinfection practices, if carried out properly, may destroy nearly 100 percent of the bacteria in wastewater, while viral destruction may be considerably less. It must be remembered that only one virus unit is enough to cause infection or disease in man.

a. Primary Treatment

Primary treatment usually consists of screening and degritting to remove large particles and debris, and sedimentation to remove suspended solids. This treatment method is probably the most widely used, however, it is the least effective. Primary treatment, without disinfection, removes virtually no viruses at retention time two to three hours, which is the design value used for most treatment plants (86).

b. Secondary Treatment

After primary treatment is used to remove solids by physical means, secondary treatment may be employed to remove organics biologically. Secondary treatment systems rely on biological cultures to convert the water soluble organics of primary treated effluents to water insoluble organics, carbon dioxide, water and energy. The two most common biological treatment processes are the trickling filter and the activated sludge process.

Trickling Filters

In the trickling filter system, primary effluent is sprayed on a bed of crushed rock or other media coated with biological slimes. These slimes consist of bacteria, protozoa, algae and fungi which build up on the crushed media and break down organics in the wastewater. Kelley et al found virus removal by this system ineffective, as they found 70 percent of samples of trickling filter effluent to be positive for viruses (87). Shuval, in a series of tests with trickling filters effluents recovered 22 - 100 percent of the viruses present in influents (11). Trickling filters are not effective in virus removal because large organic compounds present in sewage are more readily adsorbed than smaller viruses. Also, even when viruses are adsorbed, they may later be replaced and leach out of the filter system (88).

Activated Sludge

Activated sludge treatment usually consists of sedimentation followed by aeration in a basin with air diffusers or mechanical aerators to provide aeration and mixing. The mixture of wastewater and sludge is then pumped to another sedimentation basin where solids settle out. A portion of the sedimentation basin sludge, which accumulates a population of aerobic bacteria, is recycled to the aeration basins to be combined with incoming raw waste. The aerobic micro-organisms in this sludge metabolize, biologically flocculate, and remove organic components of the wastewater.

Tests performed on wastewater in a continuous flow laboratory unit have shown that, at a retention time of approximately seven hours, 98 percent removal of coxsackie virus A9 and 90 percent removal of polio virus 1 may be achieved. Removal of coliforms and fecal streptococci under the same conditions exceeded 96 percent (89). Experiments performed in the absence of activated sludge seed have shown much lower virus removals (89) and experiments carried out in the absence of air have shown no virus removal at all (90). This indicates that the constituents of activated sludge as well as aeration are important factors influencing removal of viruses. Pathogen removal in this process is largely a physical process brought about by adsorption and sedimentation, although some studies indicate that some virus inactivation may occur due to antiviral substances (90). Thus, viruses are still active in the sludge and must be treated to eliminate their pathogenic potential.

Experiments in the field have shown lower virus removals (53-90%) indicating that this process requires further treatment to effectively eliminate public health hazards.

c. Disinfection

All treatment processes are usually followed by some form of disinfection. Disinfection is a form of specialized treatment for the destruction of harmful disease-producing organisms. The most common disinfectant in use is chlorine, although chemicals such as bromine, iodine, ozone, and treatment with ultra-violet radiation are effective.

Efficiency of disinfection depends on many different factors such as the kind and concentration of organisms to be destroyed, the kind and concentration of disinfectant, contact time, the chemical and physical character of the water to be treated (91), and the availability of quick reliable methods to test for residual disinfectant concentrations. In general, viruses and parasitic cysts are more difficult to destroy than bacteria. Existence of clumps of viruses may contribute to their resistance to disinfection (92). Disinfectants also vary in their mode of inactivation. Ozone and the halogens, such as chlorine, bromine, and iodine, inactivate bacteria by penetrating the cell wall and oxidizing essential cellular functions units such as enzymes (92). Inactivation of viruses by these substances results from denaturation of the protein capsid leaving the nucleic acid core unaffected. Ultraviolet radiation is thought to kill viruses by the point heat effect. When an ultraviolet photon hits a RNA molecule in the virus, the temperature rise is enough to cause disruption of the molecule or part of the molecule (92).

Chlorination

Chlorine when applied to water of low pH (below 6.0), hydrolyzes to form HOCl, hypochlorous acid, one of the fastest virucides known. In waters of higher pH, HOCl dissociates to form H+ and OCl-. The hypochlorite ion, OCl-, is also an effective disinfectant; however, it is 60 to 70 times slower than HOCl (93). Both HOCl and OCI- in water are lumped under the term "free residual chlorine." However, the disinfecting potential of chlorine is usually greatly reduced, as most treatment plant effluent contain a large concentration of ammonia, and organic nitrogen compounds which, at high pH, combine with chlorine to form chloramines (termed as "combined chlorine"). Chloramines destroy bacteria at a rate up to 270 times slower than HOCl (93). Viruses are more difficult to destroy than bacteria. Although a chlorine residual of .5 mg/l for 15 minutes is commonly used for bacterial removal, chlorine residuals of 9 mg/l for 15 minutes and 21 mg/l for 10 minutes, especially if the chlorine is in combined form, have been reported necessary to inactivate 90-99% viruses in secondary effluents (94, 95).

Few studies have been done on disinfection of viruses in wastewater and it is impossible to set a fixed free chlorine concentration and contact time for inactivation of all viruses in all types of water. Liu's study of effects of chlorination on viruses in Potomac River water shows the wide range of resistances among different virus types to chlorine (Table 10) (96). The dosage time combination depends on the virus destruction desired, and the pH and temperature of the water (97). In general, it has been found that a rise in temperature of 10^{o}C increases the destruction rate by 200-300 percent (93). Effective destruction of viruses also requires low ammonium ion and organic concentration of the water, low turbidity, and low virus concentration (97). Thus, other methods of treatment which commonly precede chlorination are quite necessary as not only do they reduce the virus concentration, but they also remove substances that interfere with the disinfection process or protect the virus particles from contact with chlorine.

TABLE 10

RELATIVE RESISTANCE OF 16 HUMAN ENTERIC VIRUSES TO 0.5 mg/l FREE CHLORINE IN POTOMAC WATER (pH 7.8 & 2°C) (96)

Virus	Experimental Min. for 99.9% inactivation
Reo 1	2.7
3	< 4.0
2	4.2
Adeno 3	< 4.3
Cox A9	6.8
Echo 7	7.5
Cox B1	8.5
Adeno 7a	12.5
Polio 1	16.2
Echo 29	20.0
Adeno 12	23.5
Polio 3	30.0
Cox B3	35.0
B5	39.5
Polio 2	40.0
Echo 12	> 60.0

Chlorine does have its disadvantages. Large concentrations of chloramines in water are toxic to fish and other river life. Also, chlorine may react with residual organic compounds to form potentially hazardous chlorinated organics (80). The transport and handling of chlorine may also be a hazard to the public health, as it is poisonous to humans and fatal in gaseous form at levels above 1,000 ppm. Finally, chlorine is currently in short supply due to the high energy requirement for its manufacture.

Ozonation

Ozone (O_3) is a powerful disinfectant that is manufactured by the action of strong electrostatic discharges in air, oxygen, or a mixture of both. A review of literature shows ozone may be more effective than chlorine in inactivating viruses and persistant parasitic cysts (98). Research shows that as the dose of ozone is increased, there is little improvement in the disinfecting ability until a critical dose is reached. However, when the critical dose is reached, ozone is virtually 100 percent effective, and an ozone residual appears. A reasonable dose for destruction of bacteria is 1.5 to 2 ppm (99).

As for viruses, Pavoni et al, showed that an ozone dosage of 15 mg/l and an ozone residual of .015 mg/l for five minutes killed 100 percent bacteria phage f_2 (bacterial virus) in secondary effluent (99). Bender states that an ozone residual of .5 mg/l for four to five minutes in the effluent from an advanced waste treatment plant will destroy 100 percent poliovirus 1 (100).

Ozone is less sensitive to temperature and pH than chlorine, and therefore more reliable than chlorine under varying water conditions. Also, it doesn't react with ammonia to form substances toxic to fish. Ozone, however, does have its disadvantages. Because it has such a short half-life in water, it does not leave any residual protection. Another disadvantage is that in heavily polluted waters, it may rupture organic molecules into fragments that are more easily metabolized by micro-organisms, thus promoting slime growth (101). Ozone, like chlorine, may be poisonous to humans. However, it must be generated on site, thus it does not present a transportation hazard. These disadvantages must be weighed against the fact that ozone, as opposed to chlorine, creates practically no secondary pollutants.

d. Coagulation-Sedimentation

Coagulants are added to water and wastewater to aggregate suspended solids so that they may be removed by settling. Suspended solids usually have a negative charge in water, and are attracted to the positive charge of the coagulant cation (such as the Ca++ in lime). This process has another benefit as at higher pH values found in wastewater, viruses take on a negative charge and they may also be attracted to the cations of the coagulant. Usually coagulation is followed by flocculation, a process that aggregates coagulated particles together by agitation into a settleable mass called a "floc." In general, both bacterial and virus removal is a result of good floc formation which

depends on adequate coagulant concentration, absence of interfering substances such as organic matter, high pH, and proper agitation (93). Virus removal results from the formation and settling of a co-ordination complex between the cation and carboxyl groups on the viral protein coat.

Chang et al (102) studied the effects of two stage coagulation and flocculation on Ohio River water. A dosage of 25 mg/l alum or ferric chloride was used at each stage. The results of this study are given in Table 11. It can be seen from this table that virus removal parallels reduction of turbidity.

In another study by Chaudhuri and Engelbrecht (103), a dose of 40-50 mg/l alum in diluted wastewater removed 96-97 percent bacteriophage T_4 and 90-94 percent bacteriophage MS_2. In undiluted wastewater, percentage removal was greatly reduced due to the presence of interfering organic matter.

Ferric chloride may produce results similar to alum, only at higher doses. Manwaring et al (104) observed that a dose of 50-60-ppm ferric chloride brought about 99.3 percent removal of bacteriophage MS_2 in water. However, when 200 mg/l of sewage was added to the water, there was only a 67.2 percent reduction of the virus. These studies point to the fact that the coagulation sedimentation process is most effective on effluents that have already been treated to remove organic matter.

Coagulation of activated sludge effluent with lime has resulted in greater than 95 percent removal of poliovirus 1 when the lime dosage was above 400 ppm (105). At lime concentrations over 400-500 ppm, the pH of the water is raised above 11.1, which is sufficient to destroy viruses quite rapidly.

As viruses are usually only physically removed by coagulation sedimentation, (except in the case of lime) they remain active in the sludge. Thus, proper care must be taken with sludge disposal.

e. Filtration

The main purpose of the filtration process is to remove suspended solids. Filtration is more efficient when used to remove viruses and bacteria from coagulated water and wastewater. Its efficiency will depend on many variables, especially filtration rate. Gilcreas and Kelley found that rapid sand filtration of coagulated spring water resulted in low removal of coxsackie virus A5, while slow sand filtration resulted in almost 98 percent removal of the virus (106). Berg found that slow sand filtration of a lime flocculated effluent resulted in 82-99 percent removal of poliovirus (105). As lime flocculation had resulted in 70-98.6 percent removal at doses from 200-500 mg/l, the total virus removal for coagulation sedimentation filtration was 98.6-99.9 percent.

TABLE 11

Effect of Flocculation: Laboratory Study on the Removal of Virus, Bacteria, and Turbidity from Raw Ohio River Water (102)

			% Removal		Turbidity (ppm)**		
Temperature C	State of flocculation	Coagulant	Coxsackie-virus A2*	Coliforms	Initial	Final	Final pH
	1	$Al_2(SO_4)_3$	96	99	40–135	1–5	6.7–7.4
5	2	$FeCl_3$	94	62	1–5	0.1–1	7.3–7.7
	1 and 2		99.6	99.95	...	0.1–1	...
	1	$Al_2(SO_4)_3$	95	94	140–255	1–5	6.7–7.4
15	2	$FeCl_3$	92	82	1–5	0.1	7.3–7.7
	1 and 2		99.6	99.9	...	0.1	...
	1	$Al_2(SO_4)_3$	99	99.8	16–240	1–5	6.7–7.3
25	2	$FeCl_3$	94	94	1–5	0.1	7.3–7.8
	1 and 2		99.9	99.9	...	0.1	...

* Virus seeded into raw water before flocculation.
** Good flocs formed in all experiments.

Some plants filter coagulated raw water without sufficient time for flocs to settle. This may be efficient at first, but eventually floc breakthrough will occur along with virus breakthrough. It has been found that after adequate settling, even rapid sand filtration of flocculated effluent may be effective; however, oftentimes coagulation flocculation alone will bring about the same result (107). In this process, the virus is not destroyed, but only physically removed by adsorption of the virus-cation complex on sand.

2. Removal of Chemical Hazards

a. Removal of Trace Metals

Low levels of trace metals are often present in water due to industrial discharge. While such levels do not have an immediate public health impact on bathers, they may present long term hygienic hazards when they are constantly present in mans water supply or become concentrated in mans food chain.

Neither primary nor secondary treatment are dependable processes for the removal of all trace metals. It has been found that lead and cadmium can be removed by typical primary treatment involving neutralization of equalized wastewater. In such a process the metals would precipitate out in the hydroxide form (108). However, such a process is not effective for all metals. Barth et al (109) in a study of the effects of chromium (Cr + 6) copper, zinc, and nickel on different treatment processes found removal to vary from 28% for nickel to 89% for zinc in primary sedimentation followed by activated sludge treatment.

More advanced treatment is needed to insure removal of all metals, and effective removal techniques have yet to be developed for all metals. Linstedt et al (110), studying the removal of cadmium, chromium, silver and selenium by an advanced treatment process consisting of coagulation and settling with lime, sand filtration, activated carbon and cation-anion exchange found concentrations of heavy metals to be greatly reduced by this process. Lime coagulation alone was quite successful (greater than 90% removal) in the removal of cadmium and silver. This degree of effectiveness was possibly caused because the metals were present as cations, and could easily be settled out in their hydroxide form.

Linstedt also found activated carbon to be quite effective in the removal of silver, cadmium and chromium, and ion exchange to be effective in the removal of greater than 95% of all the metals studied. In another study, Hinden found reverse osmosis to remove 70% cadmium, and 95% chromium from secondary effluents (111).

Trace metals may also have adverse effects on biological treatment processes. Barth (109) studied the effects of chromium (Cr + 6) copper, nickel and zinc on the activated sludge treatment process. Lowered treatment efficiency was measured by an increase in BOD, COD, and turbidity. It was found that the following doses of these

metals would significantly reduce the effectiveness of activated sludge treatment:

Metal	Concentration in Influent (mg/l)
Chromium (Cr + 6)	10
Copper	1
Nickel	1 to 2.5
Zinc	5 to 10

It was also found that activated sludge treatment could take a much larger slug dose of these metals before effects would become harmful. Generally, the effects of slug doses depended on waste volume, the form of the metal, and the volume and character of the dilution water. Metals may also inhibit the nitrification process, causing large concentrations of ammonia in the treatment plant effluent. Large concentrations of ammonia greatly reduce the effectiveness of disinfection by chlorination.

Barth (109) also studied the effects of trace metals on the anaerobic digestion of primary and secondary sludges. The following concentrations of metals were found to be harmful to the digestion process:

Metal	Concentration in Influent (mg/l) Primary Sludge	Combined Sludge
Chromium (Cr + 6)	750	750
Copper	10	5
Nickel	740	710
Zinc	10	10

Slug doses did not produce harmful effects, probably because the digestors were not in the main flow of treatment.

b. Removal of Nutrients

In many areas removal of the nutrients nitrogen and phosphorous from wastewater is essential, since these two elements have critical control over biological activity in ecosystems. Overabundance of these elements in the water environment may create excess plant growth which eventually results in the deterioration of water quality. Nitrogen in nitrate form is also a hazard in water used for drinking water, as concentrations above 10 mg/l as nitrogen may cause methomoglobinemia in infants (see page A-22).Methods for phosphorous and nitrogen removal are discussed below.

(1) Phosphorous Removal

The removal of phosphorous compounds may be achieved through chemical biological treatment, chemical physical treatment or ion exchange. (112).

Chemical biological phosphate removal is accomplished by addition of a certain chemical to the aeration tank of an activated sludge unit or the filter influent of a trickling filter plant. Within the activated sludge unit, precipitation of phosphorous occurs in the aeration tank, and phosphorous is removed in the waste activated sludge. This process can produce an effluent with phosphorous concentrations of 1-2 mg/l (112). A variety of chemicals, including iron and aluminum salts and lime have been reported equally effective, and phosphorous removals of over 90% have been attained with the correct chemical to phosphorous ratio.

Another method for phosphorous removal is chemical-physical treatment in which phosphorous is removed through coagulation precipitation followed by filtration. Pilot plant studies performed by Bell et al (113) found removals by this type of system to exceed 90%.

Yee (114) has demonstrated that ion exchange, using activated alumina type A exchange resin, can achieve 99% removal of ortho-phosphate. Advantages of ion exchange over chemical precipitation are that ion exchange is more highly selective for phosphorous; it involves no addition of extraneous ions; it has no effect on the pH of the water; it is not affected by variations in feed water quality, and it can achieve higher removals. However, fouling of ion exchange beds with solids and organic matter, make chemical precipitation the preferred method of phosphorous removal in locations where it is feasible.

(2) <u>Nitrogen Removal</u>

Nitrogen removal may be achieved by the nitrification-denitrification process (112). Most of the nitrogen in wastewater is in the form of ammonia. Nitrification is the process by which ammonia is oxidized by the bacteria Nitrosomonas to nitrite. The nitrite is subsequently oxidized to nitrate by the bacteria Nitrobacter. The nitrifying bacteria involved in this process use inorganic carbon present in activated sludge units as an energy source. Although nitification does occur in the activated sludge units, the process requires longer aeration times and lower food to mass ratios than normally found in conventional activated sludge treatment.

Denitrification is a process by which nitrates are converted by bacteria to nitrogen gas. Denitrifying bacteria require organic sources of carbon for energy and growth. Since most of the organic carbon present in wastewater has been oxidized by the activated sludge process, an external source of organic carbon is needed. Methanol is most commonly used as a carbon source, and it is usually added to carbon packed columns, where denitrification takes place. One mole of nitrogen requires approximately 5/6 mole of methanol for complete denitrification. With proper design, this process can achieve 90% nitrate removal. One problem involved in this process is slime formation in the carbon column. While slime will not interfere with the adsorption capacity of the carbon, its sloughing off can cause problems in further treatment processes.

Ammonia stripping is another effective method for nitrogen removal. In this process ammonia ions are converted to ammonia gas. This process begins by raising the pH of the wastewater to high levels by the addition of lime, as ammonia in water of high pH exists in a dissolved gaseous state, which can easily be liberated from wastewater. The water is then pumped to a cooling tower where it is broken into fine droplets that allow rapid transfer of ammonia gas from the water to the air. At warm temperatures, almost 95% nitrogen removal can be achieved (112). However, at temperatures below freezing ammonia removal drops considerably. Scale formation resulting from the addition of lime is also a problem, necessitating periodic shutdown of the cooling tower for cleaning.

B. Land-Oriented Treatment

The Federal Water Pollution Control Act Amendments of 1972, with their goal of zero discharge, place a greater emphasis on land treatment of wastes than any previous water pollution legislation. Section 201 of the Act (Grants for Construction of Treatment Works) encourages the recycling and reclamation of wastewater and the consideration of appropriate alternative waste management techniques providing for either recycling or reclaiming of wastewater or some other form of elimination of direct discharge of pollutants.

In Section 212 (2) (A) of the Act the definition of treatment works includes land used as an integral part of the treatment process. Thus, the Amendments of 1972 not only aid the implementation of land treatment techniques, but encourages land treatment in areas where it is practicable.

Before the hygenic effects of effluent applied to the land can be evaluated, it is necessary to know the characteristics of the water being applied. The constituents of raw sewage and treatment plant effluents depend on the character of the municipal water supply, the industrial mix of the community, the proportion of commercial to residential development, and the nature of the residential community (115).

Pretreatment of raw waste is essential in land application to protect the public health, remove odors, and to improve the operational efficiency and reliability of the system (116). It is generally recommended that secondary or higher treatment be provided before land application, as this degree of treatment provides greater efficiency in the removal of hazardous substances. Table 12 lists drinking and irrigation water standards, as well as concentrations of substances in secondary treatment plant effluents. If proper techniques are followed, renovative mechanisms in the soil matrix will adequately decrease concentrations of hazardous substances. The major renovation mechanisms at work in the soil matrix include: uptake by plant roots, precipitation, adsorption, oxidation, ion exchange, and filtration (116). The effectiveness of these mechanisms in the removal of materials hazardous to the public health must be considered in the design of a land application system to insure the protection of both water and food supplies.

TABLE 12

Selected Drinking-Irrigation Water Standards vs. Typical Secondary Effluent Characteristics (28)

Substance	Drinking water (mg/liter)	Irrigation water (mg/liter)	Controlling*** concentration (mg/liter)	Secondary effluent (mg/liter)
BOD	1*	-	1	25
COD	1*	-	1	70
$+NH_4$ (as N)	-	-	-	9.8
$-NO_2$ (as N)	-	-	-	0.0
$-NO_3$ (as N)	10	-	10	8.2
P	-	-	-	10
Phenols	0.001	-	0.001	0.3
Cadmium	0.01	0.005	0.005	0.1
Chromium	0.05	0.005	0.005	0.2
Copper	1.0	0.2	0.2	0.1
Iron	0.3	-	0.3	0.1
Lead	0.05	5.0	0.05	0.1
Manganese	0.05	2.0	0.05	0.2
Nickel	-	0.5	0.5	0.2
Zinc	5.0	5.0	5.0	0.2
Boron	-	0.75	0.75	0.7
Chlorides	250	-	250	100
Sulfates	250	-	250	125
Suspended solids	-**	-	5	25
Color	15	-	15	
Taste	Unobjectionable	-	Unobjectionable	
Odor	3	-	3	
Turbidity	5	-	5	
Aluminum	-	1.0	1.0	
Beryllium	-	0.5	0.5	
Selenium	0.01	0.05	0.01	
Silver	0.05	-	0.05	
Vanadium	-	10.0	10.0	
Arsenic	0.05	1.0	0.05	
Barium	1.0	-	1.0	
Cyanides	0.2	-	0.2	
Cobalt	-	0.2	0.2	

* Carbon chloroform extract to measure organic contaminants.
** Suspended solids should approach turbidity requirements.
*** Maximum concentration acceptable in water used for both drinking and irrigation purposes

1. Removal of Biological Hazards

Proper disinfection of effluents may remove almost 99% of pathogenic bacteria. However, viruses and parasitic ova are more resistant to the disinfection process.

Pathogens are further removed from wastewater when applied to the land by a combination of straining, die off, sedimentation, entrapment, and especially adsorption (117). A considerable amount of field observations indicate that bacteria are removed from wastewater as they percolate through the soil. In fact, 92-97% of the pathogenic organisms present in wastewater effluent have been found to be removed in the upper 1 cm layer of the soil (119) if effluents are adequately chlorinated. Viruses may be transported to greater depths due to their smaller size, however, the distance is minimal. Drewry and Eliassen (120) determined that the passage of wastewater through 40-50 cm of agricultural type soil is very effective in virus removal, provided there is an absence of direct chanelling through fissure, fractures, and dissolution channels or substrata with low adsorption capacity. They also found that virus retention in the soil is basically an adsorption process that is greatly affected by pH and cation content of the water-soil system. Viruses are amphoteric (functioning as a cation or anion) in behavior. As the pH of the water soil system increases, there is an increased ionization of carboxyl groups on the virus protein sheath, which causes the virus to act as an anion (negatively charged particle). At the same time, the negative charge on soil particles increases with rising pH. However, the iso-electric point (point at which a substance is electrically neutral) of soil particles is less than that of viruses. At pH values between 7.0 and 7.5, viruses will behave as cations (positively charged particles), and are adsorbed by the anionic soil particles. If the pH of the soil is higher than 7.5 the cation content of the wastewater may lower the repulsive forces between soil and virus, allowing adsorption to take place. Besides pH, virus adsorption was also found to depend on ion-exchange capacity, clay content, organic carbon and glycerol retention capacity of the soil (120). Both viruses and bacteria are adsorbed but not destroyed, their survival and potential threat in the soil is discussed in the section, Effects of Residuals in Soils.

2. Removal of Chemical Hazards

Nitrogen Removal

Biologically treated waste usually contains 5-30 mg/l total nitrogen (22). Nitrogen compounds are of great concern in the renovation of wastewater by land disposal, as concentrations of nitrate (NO_3) above 10 mg/l as nitrogen in drinking water present a potential threat of methemoglobinemia, a disease of infants which reduces the oxygen carrying capacity of blood.

Nitrogen in wastewater is found in four forms: organic, ammonium, nitrate and nitrite. The concentration of nitrite in wastewater is usually quite low as it is readily oxidized to nitrate in the presence

of oxygen. Organic nitrogen, when applied to the land is filtered out and decomposed to ammonium. Ammonium is preferentially adsorbed by agricultural soils and is bound tightly in this form. In this adsorbed phase, it is available to plant uptake, or under aerobic conditions, conversion to nitrate. Nitrates are not tightly bound to the soil and can be removed by plant uptake or denitrification to nitrogen gas. Denitrification depends on both anaerobic conditions in the soil and soil carbon content as carbon is the source of energy for denitrifying bacteria. If nitrates are not denitrified, they may leach to groundwater or eventually reach surface waters where they may pose a threat to the public health. In general, nitrate removal varies from 0-95 percent depending on soil type, carbon to nitrogen ratio, depth of soil column, design and mode of application of the wastewater, and vegetative cover (118).

Removal of Trace Metals

Trace metals comprise another category of wastewater constituents that are of concern from a public health standpoint, as toxic effects may accompany their ingestion at low intake levels. Retention of trace metals in the soil is brought about by adsorption, ion exchange, and to some extent, precipitation (116). Retention depends on the soil characteristics. Clean soils, such as sands and gravel, have little capacity to fix heavy metals and other inorganics primarily because they lack in situ organics and clay minerals which bring about adsorption and ion exchange (28). Anaerobic conditions in the soil tend to lower pH, as such conditions cause micro-organisms to generate volatile acids. At low pH, retained metals may be leached. However, addition of lime can raise pH and ensures fixation of metals (115). When both surficial and subsurface soil become saturated, heavy metals may not only leach out to contaminate water supplies but also destroy micro-organisms needed for removal of other contaminants (28). According to the Federal Water Pollution Control Act Amendments of 1972, toxic concentrations of trace metals should not be present in secondary effluents, thus eliminating their threat in land application.

Removal of Total Dissolved Solids

Sodium and other dissolved minerals in water are significant when direct reuse is intended. It is estimated that a single use of water for domestic purposes will increase its mineral content by 100-300 mg/l. The most common soluble salts are sodium, potassium, magnesium, and calcium sulfates and chlorides. These salts are not retained significantly by the soil. Although some constituents are removed by ion exchange, the total dissolved solids content of the wastewater does not change, as one mineral constituent is only replaced by another. Therefore, these constituents may limit the reuse cycle. High sodium content may be harmful to those suffering from cardiac, renal and circulatory disease (28).

Removal of Organics

Suspended organics are almost completely removed from wastewater by filtration. Biodegradable suspended organics are oxidized by bacteria. This overall removal generally occurs in the top five to six

inches of the soil (121) and a major portion is removed in just the top few centimeters. Dissolved organics are also usually removed by adsorption on clay and humic material. Degradable dissolved organics are easily oxidized under aerobic conditions by soil micro-organisms. However, the degradation process occurs quite slowly for resistant substances (116) such as chlorinated hydrocarbons and phenols. These substances usually remain in the soil as their leaching rate is slow. Chlorinated hydrocarbons are of increased concern if the site utilized includes application of pesticides. Some organics such as cellulose and humic substance are actually beneficial as they improve soil structure and adsorptive capacity (118).

3. Effects of Residuals in Soils

Residual Pathogens

After pathogens are removed by the soil matrix, their survival in the soil and on vegetation becomes a hygienic factor. Survival in the soil depends on the moisture content, temperature, textural and organic characteristics, aerobic and anaerobic conditions, and the activity of potentially rival microbial species. High moisture content, low temperature, and anaerobic conditions are conducive to longer survival. Competition for survival is greatest at the soil surface where there is more food due to decomposition of organic matter in the presence of oxygen. Rudolphs found *Escherichia coli* to survive longer in sterile soil than non sterile soil due to lower competition. Rudolphs also found that *Salmonella* may survive in soil for 1/2 year to a year (122). Krone and McGaughy, however, found one month to be the maximum survival time of pathogenic organisms in the soil (121). Residual pathogens in the soil are a lesser threat to the public health as they have less probable contact with people here than in their transport to ground or surface water.

Although pathogenic organisms cannot penetrate healthy plants, their survival on edible plant surfaces must also be considered. However, if irrigation is stopped one month before harvesting, raw fruit and vegetables should not become vectors of disease due to natural die off of pathogens. Sepp (27) lists survival times of various organisms in various types of media in Table 13.

Residual Chemicals

Toxic metals may enter the food chain by application of effluents and sludge to the land, and their subsequent uptake by plants. Metals applied to land used for agriculture are not a hazard to the public health unless they enter the edible part of the plant. Elements in sludge and effluents that are potential hazards are boron, cadmium, cobalt, chromium, copper, mercury, nickel, lead and zinc (123). Chromium in its Cr + 3 form does not accumulate in plants, nor does mercury accumulate appreciably in plants at levels normally found in sludges and effluents. Lead is not readily translocated to the edible parts of plants, and high phosphate levels in sludge and effluent can inhibit its uptake. Boron, copper, cobalt, nickel and zinc do accumulate in

TABLE 13

SURVIVAL TIMES OF ORGANISMS (27)

Organism	Media	Survival time
Anthrax bacteria	In water and sewage	19 days
Ascaris eggs	On vegetables	27-35 days
	On irrigated soil	2-3 years
	In soil	6 years
B. dysenteriae flexner	In water containing humus	160 days
B. typhosa	In water	7-30 days
	In soil	29-70 days
	On vegetables	31 days
Cholera vibrios	On spinach, lettuce	22-29 days
	On cucumbers	7 days
	On nonacid vegetables	2 days
	On onions, garlic, oranges, lemons, lentils, grapes, rice and dates	Hours to 3 days
Coliform	On grass	14 days
	On clover leaves	12-14 days
	On clover at 40-60% humidity	6 days
	On lucerne	34 days
	On vegetables (tomatoes)	35 days
	On surface of soil	38 days
	At -17 deg C	46-73 days
Entamoeba histolytica	On vegetables	3 days
	In water	Months
Enteroviruses	On roots of bean plants	At least 4 days
	In soil	12 days
	On tomato and pea roots	4-6 days
Hookworm larvae	In soil	6 weeks
Leptospira	In river water	8 days
	In sewage	30 days
	In drainage water	32 days
Liver fluke cysts	In dry hay	Few weeks
	In improperly dried hay	Over a year

TABLE 13 (Cont'd)

SURVIVAL TIMES OF ORGANISMS (27)

Organism	Media	Survival time
Poliovirus	In polluted water at 20 deg C	20 days
Salmonella	On grass (raw sewage)	6 weeks+
	On clover (settled sewage)	12 days
	On vegetables	7-40 days
	On beet leaves	3 weeks
	On grass	Over winter
	On surface of soil and potatoes	40 days+
	On carrots	10 days+
	On cabbage and gooseberries	5 days+
	In sandy soil - sterilized	24 weeks
	In sandy soil - unsterilized	5-12 weeks
	On surface of soil (raw sewage	46 days
	In lower layers of soil	70 days
	On surface of soils (stored sewage)	15-23 days
	In air dried, digested sludge	17 weeks+
Schistosoma ova	In digestion tanks	3 months
	In sludge at 60-75 deg F (dry)	3 weeks
	In septic tank	2-3 weeks
Shigella	On grass (raw sewage)	6 weeks
	On vegetables	7 days
Streptococci	In soil	35-63 days
	On surface of soil	38 days
S. typhi	In water containing humus	87-104 days
Tubercle bacteria	On grass	10-14 days
	In soil	6 months+
	In water	1-3 months
Typhoid bacilli	In loam and sand	7-17 days
	In muck	40 days
Vibrio comma	In river water	32 days
	In sewage	5 days

plants, bur rarely reach levels injurious to man, as severe injury to the plant will occur before these levels are reached. Therefore, the only potential hazard to man is cadmium. Cadmium can concentrate in the edible portions of plants, and can accumulate in cattle fed on grains high in cadmium content. There is no FDA limit for cadmium in plants. The best recommendation is to keep the cadmium content at less than 0.5 percent and preferably 0.1 percent, of the zinc content. By doing this, the zinc concentrations would ruin a crop before cadmium could become a health hazard (123). Although toxic metals concentrations seem to be a minor hazard to man when he is a primary feeder, it must be remembered that some of these substances may become concentrated along the food chain, presenting a threat to man as a secondary feeder.

4. Comparison of Land-Oriented Treatments

The three methods of land application are compared here on the basis of removal efficiency.

Spray Irrigation

Spray irrigation is the controlled spraying of liquid onto the land to support plant growth, at a rate measured in inches of liquid per week, with the flow path being infiltration and percolation within the boundaries of the disposal site (116). Rate of application of wastewater is usually two inches per week on soils, such as silt loam, with infiltration and percolation capacity sufficient to handle the design loading of two inches of wastewater in an eight hour period.

This method of land application is the most efficient in removing harmful substances. If groundwater is kept low, there will be no threat of pathogens as they are removed within the top few feet under optimum conditions. Loamy soils because of their large active surface area have considerable retention capacity for heavy metals by ion exchange and adsorption, especially when application rates are low.

A considerable amount of nitrogen removal results from plant uptake.

This method is also the best system for removal of organic compounds as aerobic conditions which are conducive to biodegradation exist in the soil most of the time due to alternating wet and dry periods. Also, the soil provides the right amount of penetration, and adequate contact and retention time for decmoposition of organics (118).

In general, spray irrigation is most efficient because of soil texture, low application rates and removal of nutrients by crops (116).

Rapid Infiltration

Rapid infiltration is the controlled discharge, by spreading or other means of liquid onto the land at a rate measured in feet per week, with a flow path being high rate infiltration and percolation (116).

Land application by this method is often referred to as groundwater recharge. Wastewater is usually applied to ponds for 10 to 14 days, during which anaerobic conditions exist. The pond is then allowed to dry for a period of time so that organic matter may be oxidized. Since higher percolation rates are required, coarser soil with lower clay content is needed. This type of soil has a greatly reduced active surface area and requires several hundred feet of contact to achieve the same renovation that five feet of spray irrigation column does.

Removal efficiency (percent removed/distance travelled) of pathogens by rapid infiltration is probably least efficient of land application methods; however, the distance travelled is longer, and the detention time is longer, so that percent removal is ultimately the same (118). Toxic metals must penetrate farther than in soils used for spray irrigation before they are removed due to the granular nature of the soil (116). This system is intermediate in removal of organics again due to coarser textured soils. Nitrate removal depends on the maintenance of the right balance of aerobic-anaerobic conditions in the soil. Aerobic conditions are necessary for conversion of ammonia to nitrate; and anaerobic conditions are necessary for denitrification, the prime mechanism for nitrate removal by rapid infiltration systems. Thus, nitrate removal will vary according to frequency of loading, which determines the balance of aerobic anaerobic conditions.

Overland Runoff

Overland runoff is the discharge by spraying or other means of liquid onto the land, at a rate measured in inches per week, with the flow path being downslope sheet flow (116). The clay soils used in this system are almost impervious and grass is usually planted on the site to provide a habitat for biota and to prevent erosion. Renovation is less efficient. It is achieved mainly by movement of water over the soil surface, and plant growth that filters out suspended solids and supports a bacteria population which oxidizes organic matter. There is greater threat of contamination by pathogens; removal of organics and heavy metals is reduced; and total dissolved solids removal is least efficient (116). Nitrogen removal is comparable with other land application systems.

Estimated percentage removal of different substances by the three land application methods discussed is given in Table 14 (28).

These removals are not always possible, as optimum conditions may not always be maintained. Reported or estimated removal at currently existing operations is given in Table 15 (28).

5. EPA Policy on Water Reuse

The U.S. Environmental Protection Agency, recognizing the ever increasing demand for water through population growth and changing life styles has made the following policy statements on water reuse:

TABLE 14 (28)

ESTIMATED AVERAGE PERCENT REMOVAL OF VARIOUS

SUBSTANCES BY LAND APPLICATION METHODS

	% Removal		
	SI	OR	RI
BOD	98+	98+	90-95
COD	95+	95+	90+
N	85+	85+	75-80
P	99+	85+	95+
Metals	95+	85+	95+
Suspended Solids	99	95+	99
Pathogens	99	99	99

SI - Spray Irrigation
OR - Overland Runoff
RI - Rapid Infiltration

TABLE 15 (28)

REPORTED OR ESTIMATED PERCENT REMOVAL OF VARIOUS

SUBSTANCES AT CURRENTLY EXISTING LAND APPLICATION OPERATIONS

	% Removal		
	SI	OR	RI
BOD	98+	98	80-85
COD	95+	92	50-60
N	85+	80	75-80
P	99+	40-80	50-60
Metals	95+	50	50-60
Suspended Solids	99	94	99
Pathogens	99	99	99

SI - Spray Irrigation
OR - Overland Runoff
RI - Rapid Infiltration

a. EPA supports and encourages the continued development and practice of successive wastewater reclamation, reuse, recycling and recharge as a major element in water resource management, providing the reclamation systems are designed and operated so as to avoid health hazards to the people or damage to the environment.

b. In particular, EPA recognizes and supports the potential for wastewater reuse in agriculture, industrial, municipal, recreational and groundwater recharge applications.

c. EPA does not currently support the direct interconnection of wastewater reclamation plants with municipal water treatment plants. The potable use of renovated wastewaters blended with other acceptable supplies in reservoirs may be employed once research and demonstration has shown that it can be done without hazard to health. EPA believes that other factors must also receive consideration, such as the ecological impact of various alternatives, quality of available sources and economics.

d. EPA will continue to support reuse research and demonstration projects including procedures for the rapid identification and removal of viruses and organics, epidemiological and toxicological analyses of effects, advanced waste and drinking water treatment process design and operation, development of water quality requirements for various reuse opportunities, and cost effectiveness studies.

III. PUBLIC HEALTH CONSIDERATIONS IN SLUDGE UTILIZATION AND DISPOSAL

Sludge is a liquid containing contaminants removed from wastewater by physical, chemical and biological treatments. Since a typical waste activated sludge from biological treatment contains well over 100 tons of water for each ton of solids, sludge disposal is mainly a problem of disposing of the water that is in close association with waste solids (124). Estimates of sludge produced in the United States per day range from 10,000 tons/day to 20,000 tons/day. These estimates do not include industrial users of municipal treatment plants (125).

Domestic sewage sludge is primarily organic in nature, although significant quantities of toxic chemicals such as trace metals and chlorinated hydrocarbons may be present due to plumbing systems and street and agricultural runoff. In areas where industrial wastewaters are treated, concentrations of toxic substances in treatment plant sludges are increased. Furthermore, many of the pathogenic organisms found in sewage may survive wastewater treatment processes, and are quite commonly found in sludge. Because sludge potentially contains so many hazardous substances, its disposal may have adverse effects on various phases of the environment.

Recent concern over the environmental impact of residues or sludges from wastewater treatment plant processes has led to many reports, legislation, and regulations regarding its ultimate disposal (125).

In 1970 the Council on Environmental Quality in its report, "Ocean Dumping - A National Policy," recommended that ocean dumping of undigested sewage sludge be stopped as soon as possible and no new sources allowed, and that ocean dumping of digested or stabilized sludge be phased out and no new sources allowed. In accordance with these recommendations, the Environmental Protection Agency issued an interim policy in 1971 prohibiting the issuance of grants for treatment works which would dispose of sludge to the ocean.

The Federal Water Pollution Control Act Amendments of 1972 contain many provisions that are directly related to the ultimate disposal of treatment plant residues. These provisions are listed below.

1. Under Title II of the Act the Administrator of the Environmental Protection Agency makes grants for the construction of treatment works.

2. Under Section 203(a) of the Act, each applicant for a grant submits to the Administrator for his approval, plans, specifications and estimates for each proposed project for the construction of treatment works for which a grant is applied.

3. Under section 201(d) (4) the Administrator shall encourage waste treatment management which results in the construction of revenue producing facilities providing for the ultimate disposal of sludge in a manner that will not result in environmental hazards.

4. In section 212 (2) (A) the term treatment works is defined to include site acquisition of the land that will be an integral part of the treatment process or is used for ultimate disposal of residues resulting from such works.

5. Section 405 of the Act requires that there be no ocean discharge of sludge without a permit, and permits are to be issued only when it is in the public interest.

6. Finally, section 301 requires that all publicly owned treatment plants process their waters so that effluent limitations based on secondary treatment are achieved by 1977. Secondary treatment will result in large increases of sewage sludge, since, under the definition of secondary treatment, 85 percent of suspended solids will have to be removed from municipal wastewater effluents.

Due to the influence of the CEQ report, and the sections of the Act requiring permits for ocean disposal of treatment plant sludge and a minimum of secondary treatment for all publicly owned treatment plants by 1977, the quantity of sewage sludge to be disposed of is constantly increasing. Sections 201 and 212 of the Act encourage land disposal. However, the legislation does not specify exactly what methods of sludge utilization or disposal are environmentally acceptable. The Environmental Protection Agency established a work group in 1972 to develop a positive Agency policy concerning acceptable methods, based upon current knowledge, for the utilization or disposal of sludges from publicly owned

wastewater treatment plants. This work group has drafted a policy statement which defines acceptable methods for the utilization or disposal of sludge. It is divided into two essential parts; the first part describes sludge utilization methods, in which sludge is used to serve a useful purpose beyond mere disposal, and the second part describes methods which provide only for disposal. Both parts include only methods which are considered acceptable from an environmental and in particular, a public health standpoint.

These methods are discussed below along with their public health implications.

A. Sludge Utilization Methods

These methods include stabilization and subsequent land application of sludges for agriculture, enhancement of parks, forests, and reclamation of poor or damaged terrain (123).

Stabilization of sludge reduces public health hazards and nuisance conditions such as odors and insects. It is recommended that the stabilization method used reduces influent volatiles by 40 percent, and fecal coliform counts by at least 97%. Methods of sludge stabilization are:

1. Anaerobic Digestion

Anaerobic (or oxygen free) digestion is the controlled putrefaction of raw sludge. If sewage is held in a well designed and operated digester for 30 days at a temperature of at least 30°C, up to half the organic matter (or volatile solids) will be converted to gases by methane fermentation, and the fecal coliform count will be reduced by over 97% due to natural die-off with time (125). However, it has been found that anaerobic digestion will not destroy all pathogens such as parasites and viruses. Foster and Englebrecht reviewing survival of pathogens in anaerobically digested sludge, cite studies showing that one month detention in digesters is adequate to destroy lelminth ova; however ascaris ova are not affected by three month digestion (126). Another study found the coxsackie B_5 virus to survive 30 days of anaerobic digestion.

This stabilization process is sensitive to toxic substances, such as heavy metals (127).

2. Composting

Sludge can be further stabilized by various composting systems. If composting is used, temperatures above 55°C will be reached as a result of oxidative bacterial action. After composting the material must be cured in a stockpile for at least 30 days to control odors.

3. Aerobic Digestion

Aerobic stabilization involves aeration of waste sludges

until a large part of volatile solids have been destroyed. This process is more stable than anaerobic digestion as it is not sensitive to toxic influents; however, it does not generate its own fuel gas for aeration (124).

4. Lime Treatment

As an alternative to digestion, sludge may be stabilized by lime at a pH above 12 for 3 hours. Lime treatment provides a high level of disinfection, but it does not destroy organic matter. However, if limed sludge is spread on a well aerated soil, aerobic organisms will slowly consume organic matter and no significant odors should be produced. In addition, most soils and crops are benefited by the addition of lime (125).

5. Pasteurization

Pasteurization (thermal treatment at high temperatures) is used quite commonly in Europe for digested sludge that is spread on pastures during grazing seasons. Twenty five to thirty minutes heating at 70°C is recommended to kill almost all pathogens. Heat treatment above 160°C for one half hour will destroy all living organisms. If oxygen is present, a considerable amount of organic matter will also be oxidized (124).

After stabilization, liquid digested sludge may be applied to the land by plow injection, ridge and furrow spreading, or spray application. Dried sludge or composted material from digested sludge may either be spread on the land or incorporated in the soil. Public health precautions in land application of sludges include (125):

a. Workers must be protected during transportation and application of sludge.

b. Public access to both open storage lagoons and the application site itself must be controlled.

c. When spray application is used, transport of aerosols must be minimized with low pressure, large droplet spray devices, and placement of spray nozzles close to the ground, directed in a downward direction. Wide buffer zones around the application site will also minimize the hazards of aerosols.

d. When sludge is used on crops, measures must be taken to prevent harmful contaminants from entering the food chain. All sludge application projects involving crops in the human food chain must be reviewed by the U.S. Department of Agriculture, and the Food and Drug Administration. Interim criteria for determining the maximum levels of sludge application that should be permitted on land which may be used to grow food crops are:

(1) No greater amount of sludge may be applied than calculated in equation 1

$$\text{Equation 1: Total sludge (dry wt tons/acre)} = \frac{32{,}600 \times CEC}{(ppm Zn) + 2\,(ppm\ Cu) + 4\,(ppm Ni) - 300}$$

CEC - cation exchange capacity of the unsludged soil in meq/100g

ppm - mg/kg dry wt of sludge

(2) Sludge containing cadmium content greater than 1 percent of its zinc content should not be applied to cropland.

(3) The above guidelines apply only to soil that can be adjusted and held at pH of 6.5 or greater for a period of at least 2 years after application to prevent solubilization of metals.

It is generally required that industrial users of wastewater treatment plants pretreat their wastes to minimize trace metals and other toxic chemicals.

Also, since conventional wastewater treatment does not produce a pathogen free sludge, it is recommended that sludge treated land should not be used for growth of human food crops to be eaten raw until 3 years after sludge application. Sludge applied to crops which are cooked or processed before consumption, to pastures or to forage crops should be negative for pathogens by normally applied analytical procedures.

Pathogens may survive in soil and on the surfaces of plants and fruits for time periods of a few hours to several months (see Table 3). Generally longer survival times depend on low temperatures, high soil moisture, neutral soil, presence of large amounts of organic matter, and lack of competitor micro-organisms.

e. Ponding on application sites must be eliminated to prevent mosquito breeding. Ponding may be prevented by proper grading, effective maintenance, and light application rates.

f. Groundwater which is in the zone of saturation must be protected so that water quality parameters will not exceed standards set by EPA. Soil depth to fissured rock, highly permeable gravel, or groundwater itself must be sufficient to prevent contamination. The pH of the combined sludge and soil mixture should be above 6.5 to prevent solubilization of metal ions. The nitrogen content of the sludge may limit application rates, as high nitrates are harmful in drinking water. Groundwater near sludge application sites must be carefully monitored for pathogens and other toxic substances.

g. Surface water runoff must also be controlled to prevent migration of sludge material to surface water supplies. This may be done by containment, controlled release of runoff, and erosion control methods. A typical land application site should be flat to minimize runoff, and the soil should be permeable. Vegetative covers are recommended to stabilize the soil and to control erosion and runoff. Surface water near application sites must also be monitored for pathogens

and toxic materials.

B. Sludge Disposal Methods

Disposal methods include sludge landfills involving sludge alone or mixed sludge and solid wastes and sludge incineration with disposal of resultant ash. Ocean disposal is considered acceptable by EPA in its ocean dumping regulations. It is usually permitted on just an interim basis (125).

1. Sludge Landfills

Sanitary landfills of sludge containing no free moisture either separately or mixed with solid wastes must be designed and operated according to EPA Guidelines for Land Disposal of Solid Wastes (128). To protect the public health:

a. Sludge must be stabilized.

b. A daily soil cover must be applied to the landfill.

c. Workers must be supplied with individual protection.

d. Both groundwater and surface water must be protected and monitored as in land application of sludges.

2. Sludge Incineration and Disposal of Ash

Incineration alone is a sludge volume reduction method, not a method for ultimate disposal. Ash, either in its dry form, or in scrubber water, may be disposed of in a sanitary landfill.

To protect the public health, the following conditions should be met (125):

a. The incinerator must be designed to ensure at least 95% destruction of organic compounds in incineration. Increased temperature and residence time increase the assurance for destruction.

b. Emissions from the incinerator must meet the air pollution emissions standards of performance, "New Source Performance Standards for Sludge Incinerators." Fly ash may be removed from incinerators by wet scrubbers, cyclones, electrostatic precipitators, or bag filters. However, wet scrubbers are the best removal devices as they remove, in addition to ash, nitrogen and sulfur compounds, and hydrochloric acid. Stack emissions must be constantly monitored.

c. Industry must pretreat its wastewaters to remove such toxic elements as mercury and persistant organics which vaporize on incineration.

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